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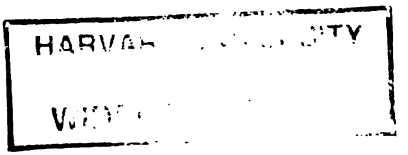

URE'S DICTIONARY

OF

ARTS, MANUFACTURES, AND MINES

CONTAINING

A CLEAR EXPOSITION OF THEIR PRINCIPLES AND PRACTICE

EDITED BY ROBERT HUNT, F.R.S. F.S.S.

Keeper of Mining Records
Formerly Professor of Physics, Government School of Mines, &c. &c.

ASSISTED BY NUMEROUS CONTRIBUTORS EMINENT IN SCIENCE AND FAMILIAR WITH MANUFACTURES

Illustrated with nearly Two Thousand Engravings on Wood

FIFTH EDITION, CHIEFLY REWRITTEN AND GREATLY ENLARGED

IN THREE VOLUMES—VOL. II

LONDON
LONGMAN, GREEN, LONGMAN, AND ROBERTS
1860

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ERRATA.

VOL. I.

Page 2. ACETATE, first line, for "by" read "in."
ACETIC ACID, fifteenth line, for "Vanquelin," read "Vauquelin."
„ 12. „ fourth line from bottom, for "of soda and acetone," read "of lime," &c.
„ 13. „ thirteenth line, for "one half of the sulphate of lime," read "one half of the acetate."
„ 64. ALCOHOLOMETRY, the last paragraph of the article is incorrect. "The duties on Scotch and Irish spirits are equalised."
„ 93. There is an error in the statement as it stands respecting Dentists' Alloy. The best authority on this subject writes: "In reply to your inquiry, I have much pleasure in informing you that 16-carat gold, which is $\frac{2}{3}$ fine gold and $\frac{1}{3}$ alloy, the alloy being nearly always equal portions of silver and copper, is not in the slightest degree injurious for dentists' purposes."
„ 146. AMMONIUM, Chloride of, in the formula, for "NH^3," read "NH^4."
„ 186. ARSENIOUS ACID, last lines, occurs this passage: "Considerable discussion has arisen from a statement made by Mr. A. S. Taylor, that the arsenic employed in paper-hangings was volatilised, &c." It should read, "from a statement made by Dr. A. S. Taylor, that the arsenic employed in paper-hangings was removed, &c." Dr. Taylor assures the editor that he never sanctioned the idea of volatilisation of the arsenical green.
„ 242. AZOBENZOIDE. Dele "See Hydrobenzamide."
„ 282. BEER, fourth line from bottom, for "Banerstock," read "Baverstock."

VOL. II.

„ 286. FORMIC ACID, for "its formula is C^2HG^2, &c.," read "C^2HO."
„ 325. GAULTHERIA OIL. Dele "which see."
„ 423. GUANO, paragraph 20, for "3. Soda lime for platinum," read "Bichloride of platinum."
„ 489. ICE-HOUSE, ninth line, for "*Fig.* 984," read "*Fig.* 985."
„ 519. Insert the initials E. S. at the end of Indigo.
„ 700. LEUCOLINE, for "a compound, &c.," read "a synonym of LEUKOL."

A

DICTIONARY

OF

ARTS, MANUFACTURES, AND MINES.

D

DAGUERREOTYPE. A photographic process discovered by M. Daguerre, a celebrated French dioramic painter, and published in July, 1839; the French Government having secured a pension for life of 6000 francs on M. Daguerre, and of 4000 francs on M. Isidore Niepce, the son of M. Nicéphore Niepce, who had for some time been associated with Daguerre in carrying forward the experiments which led to M. Daguerre's discovery.

It is rendered clear from some of Niepce's letters, that he had abandoned all hope of succeeding with iodine, upon which the sensibility of the Daguerreotype plate entirely depends. In a letter to Daguerre, Niepce says, "I repeat it, sir, I do not see that we can hope to derive any advantage from this process—the use of iodine—more than from any other method which depends on the use of metallic oxides;" and in another he writes, "A decoction of thlaspi (shepherd's purse), fumes of phosphorus, and particularly of sulphur, as acting on silver in the *same way as iodine*, and caloric, produce the same effect by oxidising the metal, for from this cause proceeded in all these instances their extreme *sensibility to light*." Niepce died in July, 1833. Daguerre proceeded with his experiments for nearly six years, before he succeeded in producing the desired results. The Daguerreotype process depends on the production of a very delicate chemical compound of iodine and silver, on the surface of a carefully prepared silver-plate. This compound is chemically changed by the radiations proceeding from any external object illuminated by the sun. The image is developed by the action of mercurial vapour, and lastly rendered permanent, as far as the action of light is concerned, by dissolving off the iodide of silver, by hyposulphite of soda. According to the first published description by Daguerre, the process is divided into five operations. The first consists in polishing and cleaning the silver surface, by friction, with cotton fleece imbued with olive oil, upon the plate previously dusted over with very finely-ground dry pumicestone out of a muslin bag. The hand of the operator should be moved round in circles of various dimensions. The plates should be laid upon a sheet of paper solidly supported. The pumice must be ground to an impalpable powder upon a porphyry slab with water, and then dried. The surface is next to be rubbed with a dossil of cotton, slightly moistened with nitric acid, diluted with sixteen parts of water, by applying the tuft to the mouth of the phial of acid, and inverting it for a moment. Two or three such dossils should be used in succession. The plate is lastly to be sprinkled with pumice powder or Venetian tripoli, and rubbed clean with cotton.

The plate is then placed in a wire frame, with the silver surface uppermost, over a spirit lamp, meanwhile moving it so as to act equally on every part of the plate. In about five minutes a whitish coating will indicate that this operation is completed. The plate must now be laid upon a flat metal or marble slab to cool it quickly. The white surface is to be brightened by rubbing it with cotton and pumice powder. It must be once more rubbed with the cotton imbued with acid, and afterwards dried by friction with cotton and pumice; avoiding to touch the plate with the fingers, or with the part of the cotton held in them, or to breathe upon the plate, since spots would thereby

be produced. After cleaning with cotton alone, the plate is ready for the next operation.

The second stage is that of iodising the plate; a box is prepared, having iodine strewed over its bottom, and the silver plate, face downwards, is placed a few inches above the iodine, and the lid of the box being closed, all is left at rest for a short time. The plate must be left in this position till the surface of the silver acquires a fine golden hue, caused by the vapours of the iodine rising and condensing upon it; but it should not be allowed to assume a violet tint. The room should be darkened, and no heat should be employed. When the box is in constant use it gets impregnated with iodine, and acts more uniformly and rapidly; but in general states of the atmospheric temperature this operation will be effected in about twenty minutes. If the purple colour be produced, the plate must be repolished, and the whole process repeated.

The plate with its golden hue is to be introduced with its frame to the camera obscura. During this transfer the light must not be suffered to strike upon the surface of the plate; on which account, the camera obscura may be lighted briefly with a small wax taper.

The plate is now submitted to the third operation, that of the camera obscura, and with the least possible delay. The action of this machine is obviously quicker the brighter the light which acts upon it; and more correct, according as the focus is previously accurately adjusted to the place of the plate, by moving backwards and forwards a roughened pane of glass, till the focal point be found; and the plate is to be inserted precisely there. This apparatus exactly replaces the ground glass. While the prepared plate is being fastened, the camera must be closed. The plate is now in a proper position to receive and retain the impression of the image of the objects presented the moment that the camera is opened. Experience alone can teach the proper length of time for submitting the plate to the concentrated rays of light; because that time varies with the climate, the seasons, and the time of day. More time should not be allowed to pass than what is necessary for fixing a distinct impression, because the parts meant to be clear would be apt to become clouded. The impression of the image of nature is now actually made upon the plate; but it is as yet invisible; and it is only after a lapse of several minutes, during which it is exposed to mercurial vapour, that faint tracings of the objects begin to be seen.

The fourth is the operation with quicksilver, which must follow as soon as possible the completion of the third. Here a phial of quicksilver, a spirit lamp, and a glass funnel with a long neck, are required. The funnel is used for pouring the mercury into a cup, placed in the bottom of an apparatus which will allow of the application of heat. No daylight must be admitted to the mercury box, a small taper only being used to examine, from time to time, the effects. The plate with the dormant image is placed some distance above the mercury, which vaporising, evokes in a truly magical manner, the delicate lines which the solar pencil has traced.

After each operation, the interior of the apparatus, and the black board or frame should be carefully wiped, in order to remove every particle of mercury. The picture may now be inspected in a feeble light, to see how far the process has succeeded. The plate, freed from the metallic bands, is to be placed in a box, provided with a cover and grooves, to exclude the light, till it is made to undergo the last operation. For the fifth and last operation the following articles are now required:—strong brine, or a weak solution of hyposulphite of soda; two troughs of tin plate, and a jug of distilled water. The object of this process is to fix the photographic picture. One of the troughs is to be filled with brine to the depth of an inch, and the other with pure water, both liquids being heated somewhat under the boiling point. The solution of hyposulphite of soda is preferable, and does not need to be warm. The plate is to be first immersed in the pure water for a moment, and transferred immediately to the saline solution, and moved to and fro in it to equalise the action of the liquor. Whenever the yellow tint of the iodine is removed, the plate is to be lifted out by the edges, and dipped straightway in the water-trough. The plate, when lifted out of the water-trough, is to be placed immediately on an inclined plane: and without allowing it time to dry, is to be floated over with the hot distilled water from the top, so as to carry off all the saline matter. As the quicksilver which traces the images will not bear touching, the silvered plate should be secured by a cover of glass, made tight at the edges by pasting paper round them.

The Daguerreotype process as thus published, although even then an exceedingly beautiful process, was not sufficiently sensitive to enable the operator to obtain portraits from the life. A period of twenty minutes was required even with the most favourable light to produce the desired effect. Numerous modifications were speedily introduced, and many of them were patented.

The progressive advance of this branch of the photographic art, though of great

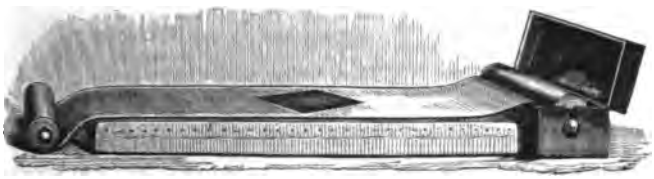
interest, cannot be dwelt on in this place. Those who are interested in the inquiry, will find the information fully detailed in Hunt's *Manual of Photography*, 5th Edition, 1857. It will be sufficient in this work to detail the more important improvements which have become generally adopted. The first advance of real importance was made by Mr. Towson, of Devonport, who has since that time distinguished himself by the introduction of his system of Great Circle Sailing. Mr. Towson suggested the use of enlarged lenses, and by acting with such, Dr. Draper, of New York, was the first to procure a portrait from the life. Still this was a tedious process, but in 1840, Mr. Goddard proposed the use of bromide of iodine, by which infinitely increased sensibility was obtained. From that time the Daguerreotype was generally employed for portraiture, until the facilities of the collodion process drove it from the field.

The improved manipulation now resolves itself into

Carefully polishing the silver plate after some of the methods previously described, and the application finally of the highest polish by the use of a buffer, the best form being that employed by M. Claudet.

In a box on a roller, to which there is a handle, *fig.* 638, is placed a long piece of

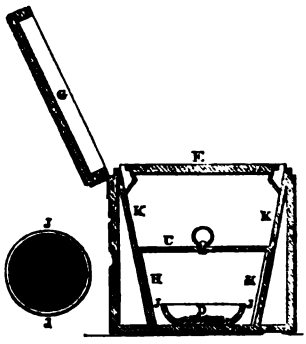
638



drab-coloured velvet, which can be drawn out and extended by means of a second roller upon a perfectly flat table. The first foot or two, for example, is drawn out; the plate which has already received its preliminary polishing is placed face downwards, and being pressed close with the fingers, a rapid circular motion is given to it, and in a few minutes it receives its highest lustre. As the velvet becomes blackened by use, it is rolled off, the portion remaining in the box being always perfectly clean and ready for use.

The iodising process follows: and for this purpose a box similar to that represented will be found to be very convenient, (*fig.* 639). This iodising apparatus consists of a square box with a closely fitting cover G, false sides are placed at an angle with this box, a cup D at the bottom contains the iodine, which is covered with a thin gauze screen J J. C is a cover which confines the iodine when it is not required for the plate; this dividing the box into two parts, H H, and K K, the former being always full of iodine vapour. When it is desired to iodise a plate, the cover C is removed, the silver plate is placed at E, and the cover G closed.

639

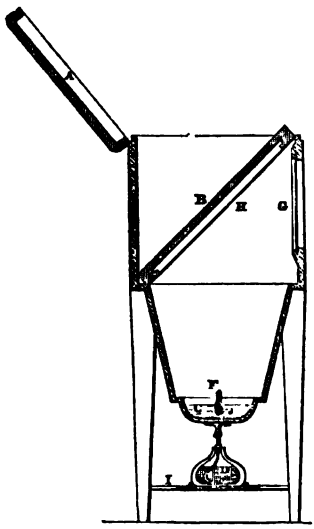


The plate is thus placed in the iodine box until it acquires a fine straw yellow colour. In another box is placed either bromine or some one of the many accelerating fluids. If bromine, or any bromide is employed, the plate should remain until it becomes of a rose colour. As a general rule, if the yellow colour produced by iodine be pale, the red should be pale also; if deep, the red must incline to violet. The proper time for exposing a plate to any of those chemical substances which are destined to produce the sensitive film, must vary with the temperature, and it can only be determined by experience. The sensitive plate is now removed to the camera obscura, for a description of which see PHOTOGRAPHY. It is scarcely necessary to say, that the plate must be preserved in perfect darkness until exposed to the image in the camera. A few seconds when the plate is properly prepared will be found amply sufficient to produce the best effect.

The impression must be developed in the mercury box (*fig.* 640) in the manner described by Daguerre. This mercurial box consists of a box mounted on legs, having a close fitting cover A, and an iron bottom in which is placed the mercury C,

and a small thermometer F to indicate the proper temperature. G is a piece of glass let into the side of the box through which the Daguerreotype plate H fixed in the frame B can be seen. D is a spirit-lamp, and I the platform on which it stands. The subject is eventually fixed by the use of hyposulphite of soda, which removes the bromo-iodide of silver and leaves a picture produced by the contrast between a combination of the silver and mercury, and the surface of the unchanged polished silver.

640



The application of chloride of gold to the finished picture was introduced by M. Fizeau.

Chloride of gold applied to the picture has the effect of fixing and enlivening the tints. A small grate being fixed by a clamp to the edge of a table, the plate is laid upon it with the image uppermost, and overspread evenly with solution of chloride of gold, by means of a fine broad camel hair brush, without letting any drop over the edge. A spirit lamp is now brought under the plate, and moved to and fro till a number of small steam bubbles appear upon the image. The spirit lamp must be immediately withdrawn. The remainder of the chloride solution must be poured back into the phial, to be used on another occasion. It is lastly to be washed and examined. This operation has been repeated three or four times with the happiest effect of giving fixity and force to the picture. It may then be wiped with cotton without injury. The process of colouring these pictures is a purely artificial one, which, while it destroys the beauty of the photograph, does not in any way improve it as a picture.

Daguerreotype Engraving.—Several processes for etching the Daguerreotype plate were introduced with more or less success. Professor Grove produced a few good engravings by the action of voltaic electricity. Berard and Becquerel were also enabled to produce some promising results by a similar process. The following process by M. Claudet was carried out to some extent with every prospect of success.

The new art, patented by M. A. F. J. Claudet on the 21st November, 1843, was established on the following facts. A mixed acid, consisting of water, nitric acid, nitrate of potash, and common salt in certain proportions, being poured upon a Daguerreotype picture, attacks the pure silver, forming a chloride of that metal, but does not affect the white parts, which are produced by the mercury of the picture. This action does not last long. Water of ammonia, containing a little chloride of silver in solution, dissolves the rest of that chloride, which is then washed away, leaving the naked metal to be again attacked, especially with the aid of heat. The metallic surface should have been perfectly purified by means of alcohol and caustic potass. For the rest of the ingenious but complex details, see *Newton's Journal*, C. S. vol. xxv. p. 112. — See ACTINISM, COLLODION, PHOTOGRAPHY.

DAHLINE, the same as INULINE. The fecula obtained from elecampane, analogous in many respects to starch. It has not been employed in the arts.

DAMAR GUM, or DAMMARA RESIN. A pale yellow resin, somewhat resembling copal, and used like it in the manufacture of varnishes. Dammara resin is said to be derived from the *Pinus dammara alba* of India. A Dammara resin is also imported from New Zealand, which is the product of the *Dammara Australis*. Under the name of Cowdie resin it is said to be used extensively as a varnish in America. "Damar is easily dissolved in oil of turpentine, and when carefully selected is almost colourless; it makes a softer varnish than mastic; the two combined, however, form an almost colourless varnish, moderately hard and flexible, and well suited for maps and similar purposes." — *Holtzapffel.*

DAMASCUS BLADES, are swords or scymitars, presenting upon their surface a variegated appearance of *watering*, as white, silvery, or black veins, in fine lines, or fillets; fibrous, crossed, interlaced, or parallel, &c. They are brought from the East, being fabricated chiefly at Damascus, whence their name. Their excellent quality has become proverbial; for which reason these blades are much sought after by military men, and are high priced. The oriental processes have never been satisfactorily described; but of late years methods have been devised in Europe to imitate the fabric very well.

Clouet and Hachette pointed out the three following processes for producing Damascus blades: 1, that of *parallel fillets*; 2, that by *torsion*; 3, the *mosaic*. The first, which is still pursued by some French cutlers, consists in scooping out with a graving tool the faces of a piece of stuff composed of thin plates of different kinds of steel. These hollows are by a subsequent operation filled up, and brought to a level with the external faces, upon which they subsequently form tress-like figures. 2. The method of torsion, which is more generally employed at present, consists in forming a bundle of rods or slips of steel, which are welded together into a well-wrought bar, twisted several times round its axis. It is repeatedly forged, and twisted alternately; after which it is slit in the line of its axis, and the two halves are welded with their outsides in contact; by which means their faces will exhibit very various configurations. 3. The mosaic method consists in preparing a bar, as by the torsion plan, and cutting this bar into short pieces of nearly equal length, with which a faggot is formed and welded together; taking care to preserve the sections of each piece at the surface of the blade. In this way, all the variety of the design is displayed, corresponding to each fragment of the cut bar.

The blades of Clouet, independently of their excellent quality, their flexibility, and extreme elasticity, have this advantage over the oriental blades, that they exhibit in the very substance of the metal, designs, letters, inscriptions, and, generally speaking, all kinds of figures which had been delineated beforehand.

Notwithstanding these successful results of Clouet, it was pretty clear that the watered designs of the true Damascus scymitar were essentially different. M. Bréant has attempted a solution of this problem. He supposes that the substance of the oriental blades is a cast steel more highly charged with carbon than our European steel, and in which, by means of a cooling suitably conducted, a crystallisation takes place of two distinct combinations of carbon and iron. This separation is, he thinks, the essential condition; for if the melted steel be suddenly cooled in a small crucible or ingot, there is no damascene appearance.

If an excess of carbon be mixed with iron, the whole of the metal will be converted into steel; and the residuary carbon will combine in a new proportion with a portion of the steel so formed. There will be two distinct compounds; namely, pure steel, and carburetted steel or cast-iron. These at first being imperfectly mixed, will tend to separate if while still fluid they be left in a state of repose; and form a crystallisation in which the particles of the two compounds will place themselves in the crucible in an order determined by their affinity and density conjoined. If a blade forged out of steel so prepared be immersed in acidulous water, it will display a very distinct Damascus appearance; the portions of pure steel becoming black, and those of carburetted steel remaining white, because the acids with difficulty disengage its carbon. The slower such a compound is cooled, the larger the Damascus veins will be. Tavernier relates that the steel crucible ingots, like those of wootz, for making the true oriental Damascus, come from Golconda, that they are the size of a halfpenny roll, and when cut in two, form two swords.

Steel combined with manganese displays the Damascus appearance very strongly.

A mixture of 100 parts of soft iron, and 2 of lamp black, melts as readily as ordinary steel. Several of the best blades which M. Bréant presented to the Société d'Encouragement are the product of this combination. This is an easy way of making cast-steel without previous cementation of the iron. 100 parts of filings of very grey cast-iron, and 100 parts of like filings previously oxidised, produced, by their fusion together, a beautiful damascene steel, fit for forging into white arms, sabres, swords, &c. This compound is remarkable for its elasticity, an essential quality, not possessed by the old Indian steel. The greater the proportion of the oxidised cast-iron the tougher is the steel. Care should be taken to stir the materials during their fusion, before it is allowed to cool; otherwise they will not afford a homogeneous damasc. If the steel contains much carbon it is difficult to forge, and cannot be drawn out except within a narrow range of temperature. When heated to a red-white it crumbles under the hammer; at a cherry-red it becomes hard and brittle; and as it progressively cools it becomes still more unmalleable. It resembles completely Indian steel, which European blacksmiths cannot forge, because they are ignorant of the suitable temperature for working it. M. Bréant, by studying this point, succeeded in forging fine blades.

Experience has proved that the orbicular veins, called by the workmen *knots* or *thorns* (*ronces*), which are seen upon the finest Eastern scymitars, are the result of the manner of forging them, as well as the method of twisting the Damascus bars. If these be drawn in length, the veins will be longitudinal; if they be spread equally in all directions, the stuff will have a crystalline aspect; if they be made wavy in the two directions, undulated veins will be produced like those in the oriental Damascus.

The characteristics ascribed to the real Damascus blades are extraordinary keenness of edge, great flexibility of substance, a singular grain of fleckiness always observable on the surface, and *a peculiar musky odour* given out by any friction of the blade, either by bending or otherwise. The author of "*Manufactures in Metals*," remarks:

"A gentleman who purchased one of these blades in the East Indies for a thousand piastres, remarked to the writer of this volume that, although the instrument was very flexible, and bore a very keen edge, it could not with safety be bent to more than 45° from the straight shape, and it was not nearly so sharp as a razor, yet, wielded by a skilful hand it would cut through a thick roll of sail-cloth without any apparent difficulty; a feat which could not be performed with an ordinary sword, nor, it should be observed, by the sabre itself in an ordinary hand, though the swordsman who tried it could, it appears, do nearly the same thing with a good European blade."

Emerson, in his letters from the Ægean, says: "I have seen some blades (scymitars) which were valued at 200 or 300 dollars; many are said to be worth triple that sum, and all retain the name of *Damascus*, though it is by no means likely that they have been manufactured there. The twisting and interwisting of the fibres of the metal are considered as the tests of excellence, but I have never seen any possessed of the perfume said to be incorporated with the steel in the real Damascus blade."

The production and use of damask steel has received much attention from the late General Anossoff, of the Corps of Engineers of the Imperial Russian army, and Master of the Fabric of Arms at Zlataoust, in Siberia. His researches and successful practice have become matters of history.

Steel helmets and cuirasses were formed of cast and damascened steel, intermixed with pure iron, a mixture supposed to combine toughness and hardness in greatest possible degree.

At different periods these works have been visited, separately, by two English travellers, Major Abbott of the Bengal Artillery, and Mr. Atkinson, who have recorded the results of observation, experiment, and conversational intercourse, and they state severally their conviction that the damask steel produced by Anossoff rivalled in beauty and excellence any works they had ever seen in other lands. They accord to Anossoff the honour of being the reviver of the art of making damask steel in Europe, while they declare the Russian natural damask steel is not approached by the fabrics of any Eastern nation now existing.

The Siberian swords and daggers were compared and tried with the choicest specimens, and found equal to the blades of Damascus, and the sabres of Khorassan; and while these valued articles might have been selected from numbers manufactured by chances of skill and material, Anossoff united chemical analyses of ores and steel, and records of observations on progressive stages, to give a true history of the means to explain and insure success. See SWORD MANUFACTURE.

DAMASCUS GUN-BARRELS. See GUN-BARREL.

DAMASK is a variegated textile fabric, richly ornamented with figures of flowers, fruits, landscapes, animals, &c., woven in the loom, and is by far the most rich, elegant, and expensive species of ornamental weaving, tapestry alone excepted. The name is said to be derived from Damascus, where it was anciently made.

Damask belongs to that species of texture which is distinguished by practical men by the name of tweeling, of which it is the richest pattern. The tweel of damask is usually half that of full *satin*, and consequently consists of eight leaves moved either in regular succession or by regular intervals, eight leaves being the smallest number which will admit of alternate tweeling at equal intervals.

The generic difference of tweeling, when compared with common cloth, consists in the intersections, although uniform and equidistant, being at determinate intervals, and not between the alternate threads. Hence we have specimens of tweeled cloth, where the intersections take place at the third, fourth, fifth, sixth, seventh, eighth, or sixteenth interval only. The threads thus deflecting only from a straight line at intervals, preserve more of their original direction, and a much greater quantity of materials can be combined in an equal space, than in the alternate intersection, where the tortuous deflection, at every interval, keeps them more asunder. On this principle tweeled cloths of three and four leaves are woven for facility of combination alone. The coarser species of ornamented cloths, known by the names of dornock and diaper, usually intersect at the fifth, or half satin interval. The sixth and seventh are rarely used, and the intersection at the eighth is distinguished by the name of satin in common, and of damask in ornamental tweeling. It will further be very obvious, that where the warp and woof cross only at every eighth interval, the two sides of the cloth will present a diversity of appearance; for on one side the longitudinal or warp threads will run parallel from one end of a web to the other, and, on the other, the threads of woof will run also parallel, but in a transverse direction across the cloth,

or at right angles to the former. The points of intersection being only at every eighth interval, appear only like points; and in regular tweeling these form the appearance of diagonal lines, inclined at an angle of 45° (or nearly so) to each of the former.

The appearance, therefore, of a piece of common tweeled cloth is very similar to that of two thin boards glued together, with the grain of the upper piece at right angles to that of the under one. That of an ornamental piece of damask may, in the same manner, be very properly assimilated to a piece of veneering, where all the wood is of the same substance and colour, and where the figures assume a diversity of appearance from the ground, merely by the grain of the one being disposed perpendicularly to that of the other.

From this statement of the principle, it results that the most unlimited variety of figures will be produced, by constructing a loom by which every individual thread of warp may be placed either above or below the woof at every intersection; and to effect this, in boundless variety, is the object of the Jacquard mounting. See LOOM, JACQUARD.

The chief seat of this manufacture is the town and neighbourhood of Dunfermline, in Fifeshire, — and Lisburn and Ardoyne, near Belfast, where it is considered as the staple, having proved a very profitable branch of traffic to the manufacturer, and given employment to many industrious people.

The material used there is chiefly linen; but many have been recently woven of cotton, since the introduction of that article into the manufacture of cloth has become so prevalent. The cotton damasks are considerably cheaper than those of linen, but are not considered either so elegant or durable. The cotton, also, unless frequently bleached, does not preserve the purity of the white colour nearly so well as the linen.

DAMASKEENING; the art of ornamenting iron, steel, &c., by making incisions upon its surface, and filling them up with gold or silver wire; it is chiefly used in enchasing sword blades, guards, and gripes, locks of pistols, &c.

Its name shows the place of its origin, or, at least, the place where it has been practised in the greatest perfection, viz. the city of Damascus, in Syria; though M. Felibien attributes the perfection of the art to his countryman, Cursinet, who wrought under the reign of Henry IV.

Damaskeening is partly mosaic work, partly engraving, and partly carving. As mosaic work, it consists of pieces inlaid; as engraving, the metal is indented, or cut in intaglio; and as carving, gold and silver are wrought into it in *relievo*.

There are two ways of damaskeening; in the first, which is the most beautiful, the artists cut into the metal with a graver, and other tools proper for engraving upon steel, and afterwards fill up the incisions, or notches, with a pretty thick silver or gold wire. In the other, which is only superficial, they content themselves to make hatches, or strokes across the iron, &c., with a cutting knife, such as is used in making small files. As to the first, it is necessary for the gravings or incisions to be made in dove-tail form, that the gold or silver wire, which is thrust forcibly into them, may adhere the more strongly. As to the second, which is the more usual, the method is this: having heated the steel till it changes to a violet, or blue colour, they hatch it over and across with a knife, then draw the ensign or ornament intended upon this hatching with a fine brass point or bodkin. This done, they take fine gold wire, and conducting or chasing it according to the figures already designed, they sink it carefully into the hatches of the metal with a copper tool.

An inferior description of damaskeen work has been introduced since the discovery of the electrotype processes. The pattern has been etched on the steel, and then gold or silver deposited into the etched lines.

DAMASSIN. A kind of damask, with gold and silver flowers woven in the warp and woof, or occasionally with silk organzine.

DAMP, *in mining* are dangerous exhalations, or rather gases, — so called from the German *dampf*, vapour — escaping from the mineral formations, or accumulating in the workings.

Fire-Damp, which occurs in coal mines, is *carburetted hydrogen gas*.

Choke-Damp, *After-Damp*, and *Black Damp*, may be regarded as Carbonic acid. See MINES, *ventilation of*.

DAPHNINE. The bitter principle of the *Daphne alpina*.

DASH WHEELS. These were revolving wheels having dash-boards, which are much used in the washing processes necessary in calico printing. See BLEACHING.

DATHOLITE. Borosilicate of lime, called also *Esmarkite* and *Humboldtite*. It is found at Arendal in Norway and in New Jersey.

Its chemical composition is, silica 37·30; boracic acid 21·32; lime 35·67; water 5·71.

DATURINE. See ATROPINE.

DEAL WOOD. See PINES.

DECANTATION. (Eng. and Fr.; *Abgiessen*, Germ.) The act of pouring off the clear liquor from any sediment or deposit. It is much employed in the chemical arts, and it is frequently effected by means of a siphon, there being less risk of disturbing the precipitate.

DECKLE, name given by the paper maker to a thin frame of wood fitting on the shallow mould in which the paper pulp is placed.

DECOCTION. (Eng. and Fr.; *Zersetzung*, Germ.) The process of boiling a liquid with some organic body, or the liquid compound resulting from the process of boiling.

DECOMPOSITION. The separation of bodies from each other. The methods employed are almost innumerable, and usually depend on the special reactions of the matters under examination. We shall consider a few of the most striking cases in both the grand divisions of the science, viz. inorganic and organic chemistry. In each instance we shall, for the sake of convenience, subdivide into the three classes of acids, alkalies, and neutral bodies. Previous, however, to this, we must glance at some of the reactions of which chemists avail themselves in separating the elements. The decomposition of ordinary metallic salts, with the view of making a qualitative analysis of a more or less complex mixture, is a problem, in general, of extreme simplicity, and directions for the purpose are to be found in all the numerous works on qualitative analysis. The principle on which the modern methods of qualitative analysis are founded, is the separation of the metals in the first place into large groups by certain reagents, and then by means of others, to subdivide into smaller groups, in which the individual metals can be determined by special tests. For the sake of simplicity, we shall only consider the more commonly occurring metals. The general reagents, by which the first subdivision is effected, are hydrochloric acid, sulphuretted hydrogen, sulphide of ammonium, carbonate of ammonia mixed with chloride of ammonium, and finally phosphate of soda. The substance in solution is treated with hydrochloric acid, by which mercury, silver, and lead are removed. The mercury will only be perfectly removed if it exists entirely in the state of a subsalt. Lead is only partially precipitated, and will be subsequently found in the next group. The precipitate by hydrochloric acid is to be boiled with water, which will remove the chloride of lead, and leave the chlorides of mercury and silver. The latter may be separated by means of ammonia, which will dissolve the chloride of silver and convert the mercury into a black powder, in which the metal can be detected by special tests. The fluid filtered from the precipitate by hydrochloric acid, is to have a stream of hydrosulphuric acid gas passed through it for a considerable time, or until no more precipitation occurs. By this means antimony, arsenic, tin, cadmium, gold, mercury, silver, lead, bismuth, and copper are thrown down, and must be separated from each other by special processes. The filtrate from the precipitate by hydrosulphuric acid is to have ammonia added in slight excess, and then a solution of sulphide of ammonium as long as any precipitation takes place. By this means nickel, cobalt, iron, manganese, zinc, alumina and chromium, are thrown down; also baryta, strontia, and lime, if they happen to be in combination with phosphoric oxalic or boracic acids, or if united to fluorine. From the filtrate, carbonate of ammonia mixed with chloride of ammonium, precipitates baryta, strontia, and lime. The filtrate from the last precipitate can only contain magnesia, or the alkalies. The above brief description of the mode of dividing the metals into groups will be sufficient to give an idea of the processes employed for decomposing complex mixtures into simple ones.

Inorganic acids are usually removed from metals by converting the latter into an insoluble compound, while the acid remains in solution either in the free state or combined with a body of such a nature as not to mask the reactions of the acid with reagents. This is often done in the laboratory by boiling the metallic salt with an alkaline carbonate. The metals are, consequently, either converted into oxides or carbonates insoluble in water, while the acid unites with the alkali to form a soluble salt capable of being obtained by filtration in such a condition as to permit the nature of the acid to be made known by means of appropriate tests. It is usually necessary to neutralise the solution carefully before testing for the acid.

It is seldom necessary in researches to reduce inorganic alkalies to their elements, their constitution being usually ascertained by converting their constituents into new forms capable of being weighed or measured with accuracy. If, for instance, it was necessary to ascertain the constitution of sulphuric acid, it would be sufficient to determine the quantity of baryta contained in the sulphate. On the other hand, acids susceptible of assuming, when pure, the gaseous condition may have their constitution determined by decomposing a known volume with a substance capable of combining with one ingredient and liberating the other in the gaseous state. Thus hydrosulphuric acid may be analysed by heating it with potassium, which will remove the sulphur and liberate the hydrogen.

In decomposing inorganic alkalies with the view of separating the metals contained

in them, we usually have to avail ourselves of very powerful affinities. This arises from the fact, that the substances in question are, generally, produced by the union of a metal with oxygen, the metal having so strong a tendency to combine with that element, that mere exposure to the air is sufficient to determine their union into a compound of great stability. In order, therefore, to decompose the alkalies of this class, it is necessary to find some substance having a powerful tendency to combine with oxygen under certain conditions. Now it has been found that carbon, if raised to an exceedingly high temperature, and employed in great excess, is capable of removing the oxygen, even from such bodies as potassium and sodium, the affinity of which for oxygen is very great.

Inorganic neutral bodies are generally decomposed either by the ordinary processes of analysis, or, where the neutrality arises from the substance under examination being a compound of an acid and a base, by separating the two by treatment with a reagent capable of combining with one to the exclusion of the other. This is a process frequently available in quantitative analysis. As an illustration, we may take the decomposition of the carbonates by a mineral acid in an apparatus which permits the carbonic acid set free to be accurately estimated by weighing. (See CARBONATES.) Another instance of the decomposition of a neutral body, by treating it with a substance capable of combining with one of the constituents and separating the other in a free state, is the decomposition of sulphate of potash by baryta. If a solution of the salt be boiled with excess of solution of baryta, sulphate of baryta is produced and caustic potash set free. The excess of baryta is removed by boiling in the air until the whole of the latter base is converted into the insoluble carbonate. A precisely analogous process is the ordinary mode of preparing caustic potash by boiling its carbonate with quicklime.

Neutral bodies are frequently, however, so constituted, that the neutrality does not arise from the circumstance of an acid being saturated with a base, but from the energies of two elements being, to some extent, satisfied by the fact of their being in combination. Thus, water is a neutral substance, nevertheless it may be decomposed by a variety of processes, several of which are susceptible of quantitative precision. In the first place, it may be decomposed by passing steam over a metal capable of uniting with its oxygen with liberation of the hydrogen. It may also be electrolysed and the two gases separately obtained.

Organic or inorganic neutral salts may, at times, be very completely and simply decomposed by means of the battery. Not only are the various processes in electro-metallurgy founded on this principle, but it has even been practically applied to the quantitative estimation of the metals in ores. The electrolysis of the neutral salt of the great series of organic acids of the general formula $C^nH^nO^4$ has thrown great light on some previously obscure points in the radical theory.

The decompositions undergone by organic substances in contact with reagents are so manifold, that the limits of this work preclude the possibility of doing more than glancing at a few of the most general and interesting. Perhaps of all the modes of inducing the breaking up of more complex into simpler substances, the application of heat is the most remarkable for its power and the varied and opposite character of the substances produced. It has been shown that, as a decomposing agent, heat possesses no special function. From complex organic molecules all classes of substances are formed. Individual substances belonging to every chemical type are, therefore, found among products of destructive distillation. Acids, alkalies, and neutral bodies of every kind are formed, and some of the most interesting and beautiful bodies known to chemists are found in the uninviting looking tar of coal. Let us illustrate this by a glance at a few of the coal-tar products. Among the acids are the oxyphenic, carbolic, and cresylic. The alkaloids represented are methylamine, ethylamine, propylamine, butylamine, amylamine, pyridine, picoline, lutidine, collidine, parvoline, chinoline, lepidine, cryptidine and aniline. Among hydrocarbons, benzole, toluole, xylole, cumole, cymole, propyle, butyle, amyle, caproyle, caproylene œnanthylene, naphthaline, anthracene, chrysene, pyrene, &c. &c. This list, probably, does not include one half of the substances produced from coal by the decomposing and recomposing influence of heat.

Mineral acids exercise a powerful decomposing influence on organic substances. Of these the nitric and sulphuric are the most commonly used. Nitric acid is especially active, owing to its twofold action. By virtue of its oxidising tendencies, it breaks up great numbers of substances into more simple and less carburetted derivatives, and the hyponitric acid produced by the removal of one of the atoms of the oxygen of the acid frequently enters into the resulting compound, a substitution product being the final result. In the latter bodies produced in this manner the hyponitric acid (NO^4) generally replaces hydrogen, the original type remaining unaltered. The production of oxalic acid from sugar; succinic, lipic, adipic, pimelic, suberic, &c., acids from oily

and fatty matters by the action of nitric acid, are examples of its oxidising power; while the formation of nitrobenzole, and bodies of more or less analogous character, present instances of the replacement of hydrogen by hyponitric acid.

Sulphuric acid owes its decomposing power to its extreme tendency to combine with water. Many of the less stable organic bodies are, by this means, absolutely broken up, so that the resulting products are of a character too indefinite to allow of the changes being expressed by an equation which shall render a true account of all the substances directly or indirectly formed. On the other hand, the action may be so controlled by the careful regulation of the temperature and strength of the acid that products may be eliminated which are themselves totally broken up and destroyed by an acid of greater strength. The production of grape sugar by the action of sulphuric acid on starch, or liguine, may be taken as an example. It not unfrequently happens, that the sulphuric acid unites with the substance acted on to form a conjugated compound. Benzole, and many other hydrocarbons, as well as oxidised bodies, behave in this manner with concentrated sulphuric acid.

Chlorine and the other halogens are powerful decomposing agents, acting chiefly by virtue of their affinity for hydrogen. The principal effects produced by them are oxidation and substitution. The oxidising action of the halogens arises from the decomposition of water; the hydrogen combining with the chlorine, &c., to form an hydracid, and the free oxygen uniting with the other substances present.

The above sketch will sufficiently indicate some of the most usual methods by which the decomposition of organic and inorganic bodies is effected; but hundreds of other decomposing agencies are at the call of the chemist, when any phenomena involving the disruptions of compounds are to be investigated. — C. G. W.

DECREPITATION (Eng. and Fr; *Verknistern*, Germ.) is the crackling noise, attended with the flying asunder of their parts, made by several minerals and salts when heated. Sulphate of baryta, chloride of sodium, calcareous spar, nitrate of baryta, and several other bodies which contain no water, decrepitate most violently, separating at the natural joints of their crystalline structure.

DEFECATION. (Eng. and Fr.; *Klaren*, Germ.) The freeing from dregs or impurities.

DEFLAGRATION. (Eng. and Fr.; *Verpuffung*, Germ.) A rapid combustion, attended with much evolution of flame and vapour. When metals are burnt by electricity, they are said to undergo deflagration.

DEFLAGRATOR. A galvanic instrument for producing a rapid and powerful combustion, introduced by Professor Hare.

DE LAINES. Properly, fine worsted fabrics. They are indeed figured muslins, which should always be made of wool, but they are frequently made of mixed material.

DELF. A coarse species of pottery originally manufactured at Delft in Holland, covered with a white enamel or glaze. See POTTERY.

DELIQUESCENT. (*Zerfliessen*, Germ.) Any solid which absorbs moisture from the air spontaneously, and becomes soft or liquid; such as potash, and chloride of calcium.

DELPHINIA. The poisonous principle of the Stavesacre.

DEMY. Paper of a particular size is so called. Drawing demy is 15 inches by 20; printing demy is 17½ inches by 22½.

DENUDATION. (*Denudo*, to lay bare.) The carrying away by the action of running water of the superficial solid materials of the land, by which the lower rocks are laid bare.

DEODORISERS. Bodies which have the power of depriving fetid and offensive effluvia of their odours. There appears to exist a general idea that these substances are, all of them, equally disinfectants. No greater mistake can be made than to suppose that because a preparation has the power of removing a disagreeable smell, that therefore it has removed all the elements of infection or disease. See DISINFECTANT.

To disguise unpleasant odours, fumigation is employed, many of the fragrant gums are burnt, and fumigating pastiles employed. It is also a common practice to burn lavender and brown paper, but these merely overpower or disguise the smell; they do not in any way act upon the noxious effluvia. See PASTILES. FUMIGATION.

DEPHLEGMATION. The process by which liquids are deprived of their watery particles. It is applied chiefly to spirituous liquors, but is now obsolete, as involving the alchemistical notion of a peculiar principle called *phlegm*.

DEPHLOGISTICATED, deprived of *phlogiston*, which was for a long period after the time of Stahl regarded as the principle of *levity* and of *combustion*. It may be regarded as synonomous with oxygenated. "Others believe that *Earth* and *Phlogiston* are those principles which are the constituent parts of all corporeal substances."

"It appears from all those experiments, that in each of them *phlogiston*, the simple inflammable principle, is present." "Thus much I see from the above mentioned

experiments; that air is composed of two different fluids, the one of which attracts not *the phlogiston*, and the other has the quality of attracting it."—*Scheele: Experiments on Air and Fire.*

DEPILATORIES. Preparations for removing hair from the skin. These are said to have been much used by the ancients. In modern times they have been used as cosmetics to remove superfluous hair from the face. Lime and the tersulphuret of arsenic (Orpiment) are the constituents of most of the ancient and modern depilatories; but the use of orpiment is dangerous, especially if there is any abrasion of the skin.

The best and safest depilatory is said, in *Gray's Supplement to the Pharmacopœia, edited by Redwood*, to be a strong solution of sulphuret (*sulphide*) of barium made into a paste with powdered starch. It should be applied to the hair immediately after it is mixed, and allowed to remain there for five or ten minutes.

DEPOSITION OF METALS. See ELECTRO-METALLURGY.

DERBYSHIRE SPAR. Fluor spar, or fluoride of calcium; which see.

DERRICK CRANE. The term Derrick is applied to a temporary crane, consisting of a spar supported by stays and guys, carrying a purchase for loading or unloading goods on shipboard. The Derrick crane is somewhat similar in its plan, the projecting iron beam, or derrick, of which can be raised or lowered to any desired angle.

DESICCATION. The act of drying.

Davison and Symington patented a process for drying or seasoning timber, by currents of heated air. Even after wood has been dried in the ordinary manner, it contains much moisture, which it is still necessary to remove. The patentees have given some curious results of this desiccating process:—

Temperature of air 214°.

Violin wood.	Original weight.	Weight after seasoning.	Moisture removed.
6 pieces small and thin - -	3·38	2·87	8· per cent.
2 pieces larger - - - -	10·56	9·5	10·1 do.
2 pieces larger - - - -	25·25	22·93	9·25 do.

	Original weight.	100° after 6 hours.	120° after 10 hours.	150° after 20 hours.	180° after 30 hours.	230° after 38 hours.	Per cent.
Oak - - - -	1·84	1·76	1·71	1·59	1·56	1·51	18·1
Red pine - - -	1·5	1·4	1·38	1·33	1·28	1·25	16·6
Birch - - -	1·2	1·09	1·05	1·01	·99	·97	19·2
Mahogany - -	1·21	1·14	1·09	1·03	1·0	·98	19·2

White wood, lime tree.

	Original weight.	170° after 6 hours.	Part 140°, and part 212° after 15 hours.	After 24 hours.	After 34 hours.	After 84 hours.*	Per cent.
1	23·5	20·45	18·7	18·22	17·4	17·4	26·
2	25·19	21·33	19·37	18·9	18·07	18·0	28·5
3	23·67	19·7	17·83	17·6	16·82	16·75	29·2
4	20·08	17·07	15·8	15·6	15·13	15·05	25·

No. 3 exposed to the atmosphere for three weeks, weighed at the end of that time 17·8, or had taken in 4·2 per cent. of moisture.

Feathers.—Feather beds, mattresses, blankets, and clothing, are not only dried, but purified by this process. A feather bed of sixty pounds weight, will have no less than 100,000 cubic feet of air passed through it; and at the same time beaters are made use of, for the purpose of removing the dust. Feathers treated in this manner have their

* It will be observed, on referring to the last column of lime, that the wood, although kept in the chamber exposed to heated currents for 50 hours, weighed nothing less after the first 34 hours.—(*Whishaw*). One application of the desiccating process for timber is to expose it for some hours to the heated currents of air, and then, in its heated state, immersing it suddenly in any of the approved antiseptics, creosote or coal-tar. The result is, that the air-vessels of the wood, if not entirely empty, contain air at so very high a temperature that a vacuum is instantly formed, and every pore is immediately charged with the cold antiseptic in which the wood is immersed.

bulk and elasticity so much increased, that a second tick is found almost invariably necessary to put the feathers into.

A practical proof of the extreme powers of currents of dry heated air was given in Syria, by exposing to them sixty suits of clothes, which had belonged to persons who died of the plague. These clothes were subjected to the process alluded to, at a temperature of about 240°, and afterwards worn by sixty living persons, not one of whom ever gave the slightest symptom of being in the slightest degree affected by the malady. (*Whishaw.*) The purification of feathers by this process is carried out in many large establishments. Coffee it has been proposed to dry by currents of heated air, and subsequently to roast it by the same process.

Thick card-board, used for tea-trays and papier maché, is now frequently dried by heated air. By the plan adopted at one establishment, previously to the introduction of Davison and Symington's method, it invariably occupied from eighteen to twenty hours to dry a room full of paper by a heating surface equal to 330 feet; whereas by the new method, the same amount of work is accomplished in four hours, and with a heating surface of only 46 feet, or one seventh the area required by the former.

Silk.—For the purpose of drying silk, it has been usual to heat the drying chambers by large cast-iron globular stoves, the heat obtained thus was equal to 120° F., but excessively distressing to any stranger entering these apartments.

In one arrangement 7000 cubic feet per minute are admitted at the above temperature through small perforated iron plates, let into the stone floor. As many as 3000 pieces of silk are sometimes suspended at one time; and as each piece of silk, when wet contains about seven ounces of water, and as the operation of drying the whole occupies but one hour, it follows that about 130 gallons of water are evaporated in that time.

Yarns.—In Scotland and other places they now dry yarns by modified applications of this process; and it is indeed extensively used in bleaching establishments, in calico-printing works, &c. See *Transactions of the Society of Arts for* 1847–8.

A DRYING HOUSE is an apartment fitted up in a peculiar manner for drying calicoes, and other textile fabrics. Mr. Southworth, of Sharples, a Lancashire bleacher, obtained a patent in 1823, for the following ingenious arrangement, which has been since generally adopted, with certain modifications, in most of our extensive bleaching and printing works. *Fig.* 641, is a section of the drying-house, where *a* is a furnace and boiler for the purpose of generating steam; it is furnished with a safety valve in the tube *b*, at top, and from this tube the steam main *c* passes down to the floor of the basement story. From this main, a series of steam-pipes, as *d d*, extends over the surface of the floor, and from them heat is intended to be diffused for the purpose of warming the drying-house.

Along the middle of the building a strong beam of timber *e e* extends, and is supported by cast-iron pillars; from this beam, to bearings on the side walls, a series of rails are carried in a cross direction, over which rails the wet cloth is to be hung in folds, and the steam or evaporation emitted in drying is allowed to escape through apertures or ventilators in the roof.

The mode in which the cloth is delivered on to the rails, on either side of the beam will be best understood by reference to the delivering carriage, which is shown, with its rollers partly in section.

The wet cloth is first to be coiled upon a roller, and then placed in the carriage, as at *f*, with its pivots bearing upon inclined planes. The carriage is to placed at the commencement of the rails, running upon the middle beam, and also upon the side-bearings or railways extending along the side walls of the building, parallel to and upon a level with the same beam. It is made to travel by means of an endless band passing over two riggers *g* and *h*, in *fig*, 604, and over pulleys and a band-wheel attached to the carriage, as will be explained. The rigger *g*, which moves this endless band, is actuated by bevel gear, seen at *b*, which is put in motion by a pinion at the end of a revolving shaft leading from a steam engine.

In the same *fig.*, *k k*, is the endless band passing over a pulley under the band-wheel, and over the pulley *n*, by which it will be perceived that the traversing of the band, as described, would cause these pulleys and wheels to revolve. On the action of the band-wheel *m*, there is a drum against which the roll of wet cloth *f* presses, and as this drum revolves, the roll of wet cloth is, by its friction, made to turn in a contrary direction, and to deliver off the cloth on to the periphery of the drum, whence it passes over a roller and descends to the rails. Upon the end of the axle of the band wheel *m*, there is a pinion which takes into the teeth of the large wheel, and upon the axle of this large wheel there is a pinion that actuates the intermediate wheel which turns another toothed wheel. This last mentioned toothed wheel takes into cogs upon the side railway, and hence, as the train of wheels moves round, the carriage to which the wheels are attached is slowly impelled forward.

As soon as the wheels begin to move, and the carriage to advance, the wet cloth begins to uncoil, and to pass down over the first roller; a small roller attached to the carriage, as it passes over the rail in succession, holds the cloth against each rail for a short space of time, and prevents it from slipping, by which means the cloth descends in folds or loops between the rails, and is thereby made to hang in a series of folds or loops as shown in the figure.

It will be perceived that as the pivots of the cloth roller *f* bear upon inclined planes, the roller will continually slide down as the cloth diminishes in bulk, keeping in contact with the drum, and delivering the cloth from the roller on to the several rails, as described.

In order to stop the carriage in any part of its course, or to adjust any of the folds of the cloth, a man is usually placed upon the platform travelling with the carriage, over which he has perfect command. This apparatus may be also employed for taking the

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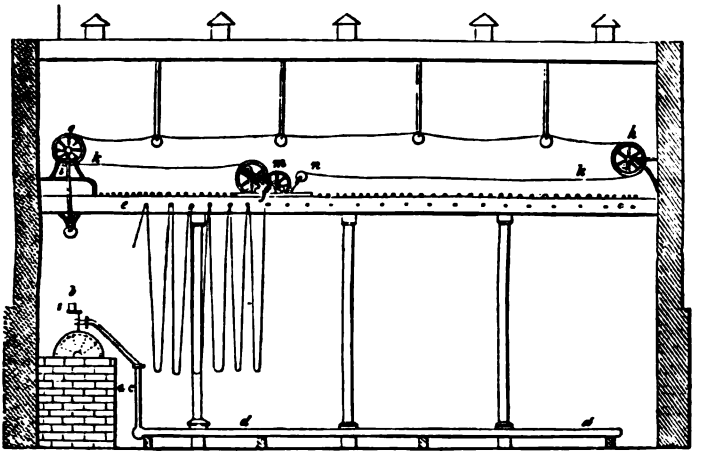

cloth when dried off the rails; in which case the carriage must be made to travel backwards, and by first guiding the end of the cloth on to the roller *f*, and then putting the wheels in a retrograde motion, the cloth will be progressively coiled upon the roller *f*, in a similar way to that by which it was uncoiled.

Drying Machine (centrifugal). (*Hydro-extracteur; Machine à essorer*, Fr.) By this contrivance, Pentzoldt was enabled to deprive all kinds of wet clothes in a few

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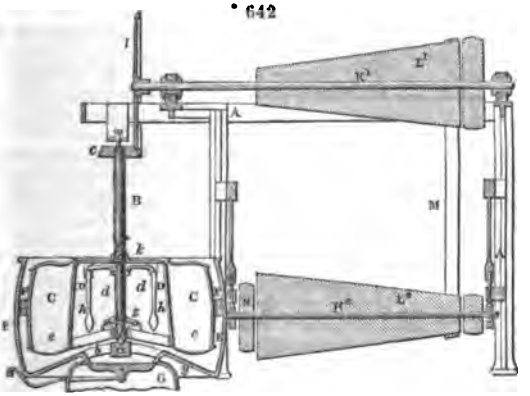

minutes of their moisture, without compression or heat. Kelly, a dyer, and Alliott a bleacher, have since obtained a patent for the above machine with improvements. *Fig.* 642, represents a partial section of the machine. A, A, is the frame; B, the

vertical shaft turning in the step *a*, fixed on the bridge *b*. This shaft bears on its upper part a friction cone *c*, from which it receives its movement of rotation, as will be presently shown; C is a drum containing two concentric compartments *d e*, of the form represented in the figure; this drum moves freely upon the shaft B, and rests when it is not in motion upon two conical projections *f*, *g*, which form a part of the shaft. These two compartments are each composed mainly of metal, and their sides consist of tinned iron wire coiled circularly at very small distances from each other, and soldered together crosswise by small strips of metal. The top which covers the inner compartment *d*, is secured by bolts and screws to a circle of iron which retains the wire sides of the same metal, but that which serves as a cover to the little compartment *e*, in which alone the goods are placed, is disposed so that it may be removed with ease, when these are to be introduced or withdrawn. It is furnished with an outer and inner border, disposed so that when the top is fixed the inner border presses upon the convex circumference of the central compartment, while the exterior border falls outside of the edges of the other compartment. While the machine is at work, the second plate is maintained in its place by pins or bolts, not shown in the figure.

The sides of the outer compartment *d*, are connected with the bottom by means of a prolongation of cross bands of metal which unite the wires and are riveted or soldered to the two outer plates. The wires of the interior compartment are attached by an iron hoop, to which they are riveted and soldered, and are united to the bottom plate by means of a rim upon this plate; a rim somewhat flattened upon the sides which are riveted and soldered.

D, is a regulator suspended in the inner compartment *d*, and whose two branches *h*, *h*, are loaded. These two branches having room to play around the bolts which serve as points of attachment, and which are fixed to the upper plate, terminate in kneed branches whose extremities rest upon a rope *g*, which projects from the shaft. E, is an exterior envelope secured to the frame A, A. It encloses the whole drum except at top, and serves to catch the water thrown out of the goods. At *y* there is a stop cock for the discharge of this water, and the bottom contains besides the end of a pipe by which hot air is introduced.

The vertical shaft B receives a movement of rotation and carries with it the drum. The more rapid this movement is the more does the centrifugal force tend to expel the water contained in the clothes or yarn to be dried. But as this force might also displace the central shaft, if the weight was not rightly distributed in the drum, and cause the dislocation of the machine when the great velocity requisite for quick drying is given to it, the regulator D is tested to prevent accident. The branches of this regulator spread wider the more the velocity is increased, and raise consequently the drum C above the conical enlargements, which permits the drum to be somewhat misplaced and to rectify its position conformably to the inequalities of its load, so that its centre of gravity may always coincide with its centre of rotation. The drum is connected with the shaft as is shown in *z*, leaving it free to take the requisite adjustment. To hinder it from rising too suddenly, a spiral spring *k* is fixed over the shaft immediately above the conical enlargement *g*. In order to maintain the equilibrium more certainly, the apparatus is surrounded with a hollow crown F, half filled with water, and if during the revolution of the machine the weight of the goods predominates on one side, that of the water which accumulates on the other side serves the more to counterbalance it. The effect of this crown may be increased by dividing it into two compartments or more. G, is a large pipe by which steam or hot air is introduced into the belly of the drum, which is pierced in this place with a great number of small holes to receive it.

The rotary movement is transmitted to the drum in the following way.

I, is a conical disc mounted upon the extremity of a shaft K^1 which actuates the cone C and the shaft B by means of friction; L^1 is a cone fixed upon the extremity of the shaft. K^2 L^2 " is another cone of the same dimension, but whose base fronts the top of the other, and which is placed on the shaft K^2" commanded by the prime mover. M is the belt which embraces the two cones, and whose lateral displacement, effected by means of a fork, permits the velocity of the machine to be regulated at pleasure. N is the pulley which directly receives the movement. In place of a single friction disc I, another may be employed, if judged necessary, and placed between the two, an additional friction pole, in order better to equalise the friction. In this case the disc and additional cone should turn freely upon their own shafts. We may also adopt another arrangement for the bottom of the vertical shaft. The shaft immediately above the step is surrounded by a loose rim, around which a certain quantity of lead shot, or other granular matter, is contained in the rim in the box which serves for the step. The top of this box is pierced with an opening, into which, when the machine is at rest, a cord connected with the shaft sinks, controlled by the shaft, and when

the drum is raised by the action of the regulator D, this cord quits its place, which allows the shaft to displace the shot a little, and to take a position conformably to the point of the centre of gravity.

But after all great attention should be paid to the proper working of the machine. There are many other drying machines used, some of which are described in the articles devoted to special manufactures.

DETONATION. See FULMINATING, for the mode of preparing detonating powder for the percussion caps of fire-arms.

DETRITUS; *de*, from, *tero*, to rub. Matter worn off rocks, and deposited in valleys.

DEUTOXIDE, literally means the second oxide, but is usually employed to denote a compound containing two atoms or two prime equivalents of oxygen to one or more of a metal. Thus we say deutoxide of copper, and deutoxide of mercury. Berzelius abbreviated this expression by adopting the principles of the French nomenclature of 1787; according to which the higher stage of oxidisement is characterised by the termination *ic*, and the lower by *ous*. It is now rarely employed.

DEVIL. The name of a spiked mill, used in Yorkshire, for tearing woollen rags into fragments for the manufacture of SHODDY.

DEVONSHIRE BATTS. A porous fine-grained sandstone from the quarries of Black Down Cliffs, near Collumpton, in repute as a grindstone.

DEVONSHIRE OIL-STONE. This stone occurs near Huel Friendship Mine, about three miles from Tavistock, in the Devonian Slates of that district. It has considerable local repute for sharpening all kinds of thin-edged broad instruments; it has not, however, become an article of commerce. — *Knight, Trans. Society of Arts.*

DEW-RETTING. See FLAX.

DEXTRINE. Starch Gum. There are three modes of obtaining this from starch, viz., by torrefaction, by the action of dilute acids, and by the action of *diastase*. The impure dextrine obtained by roasting is termed *roasted starch*, or *leicomme*. British gum is prepared by carefully roasting wheat starch, at a temperature of 300° Fahr. Another method of preparing dextrine consists in moistening 1000 parts of potato starch with 300 parts of water, to which 2 parts of nitric acid have been added. The mixture is allowed to dry spontaneously, and is afterwards heated for two or three hours in a stove, at 212 Fahr. Dextrine in many of its characters resembles ordinary gum, but it is distinguishable from it by its *right-handed rotation of a ray of plane polarised light*,—hence its name *dextrine*,—and by its yielding oxalic acid, but not mucic acid, when heated with nitric acid. Its chemical formula is $C^{12}H^{9}O^{9},HO$.

DIACTINIC LENS. A name proposed to be given to the best construction of lens for the photographic camera obscura. It should be transparent to all the chemical rays, or rather, a lens which should unite the chemical and luminous foci in one point. The name has not been generally adopted.

DIALLAGE. *Bronzite*, *Hyperstene*, and *Schillerspar* are often confounded under this name. The name is derived from διαλλαγη, difference, alluding to dissimilar cleavage. It is thin, foliated, and easily cleavable; laminæ brittle; colour, various shades of green, grey, and brown, sometimes bronze and pearly metallic.

Of diallage rock fine examples will be found near the Lizard Point, and beautiful crystals of diallage are to be discovered in the Serpentine rocks near Cadgwith, in the same locality.

DIAMAGNETISM. As this term is becoming more generally used in our language, it appears necessary to give a definition of it, although it is not our purpose to enter on the consideration of any purely physical subject.

The term was introduced by Dr. Faraday, to express those bodies which did not act as magnetic bodies do. If N and S represent the poles of a horse-shoe magnet, any bar of a magnetic character, as iron, cobalt or nickel, hung up between them and free to move, will by virtue of the attracting and repelling polar forces, place itself

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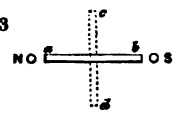

along the line joining the two poles *a b*, which is called the magnetic axis. If instead of a bar of iron we suspend in the same manner a rod of glass, of bismuth, or of silver, it will arrange itself equatorially, or across the line *a b*, as shown by the dotted line, *c d*. All bodies in nature appear to exist in one of those two conditions. The prefix *dia* is used here in the same sense as in dia-meter. See *De La Rive's Electricity*, for a full explanation of all the diamagnetic phenomena.

DIAMOND (*Diamant*, Fr.; *Diamant*, Germ.) Experiment has determined that

this beautiful gem is a peculiar (*allotropic*) condition of carbon. By burning the diamond in oxygen gas we produce carbonic acid; and by enclosing the gem in a mass of iron, and subjecting it to a strong heat, the metal is converted into steel, when the diamond has disappeared. It has been shown that we can, by the agency of the heat of the voltaic arc, convert the diamond into excellent coke, and into graphite; but although portions of coke are found to be sufficiently hard to cut glass, we have not yet succeeded in making diamonds from coke. Sir Humphry Davy noticed that the charcoal of one of the poles of Mr. Children's great voltaic battery was considerably hardened, and he regarded this as an advance towards the production of that gem. Recently some experiments made by a French philosopher have advanced the discovery another step: one of the poles of a voltaic battery being charcoal and the other of platinum, it was found that the fine charcoal escaping from the carbon pole and depositing itself on the platinum pole was sufficiently hard to be used in the place of diamond dust for polishing gems. The formation of the diamond in nature is one of the problems which "our philosophy" has not yet enabled us to solve. Time is an element which enters largely into nature's works; she occupies a thousand, or even thousands of years to produce a result, while man in his experiments is confined to a few days, or a few years at most.

Although diamonds have been occasionally found in various parts of the globe, there are only two places which can be strictly named as diamond districts, a portion of the Indian Peninsula and Brazil. India has been celebrated from the most remote antiquity as the country of diamonds. Its principal mines are in the kingdoms of Golconda and Visapour extending from Cape Comorin to Bengal, at the foot of a chain of mountains called the *Orixa*, which appear to belong to the trap rock formation. In all the Indian diamond soils, these gems are so dispersed that they are rarely found directly, even in searching the richest spots, because they are enveloped in an earthy crust, which must be removed before they can be seen. The stony matter is therefore broken into pieces, and is then, as well as the looser earth, washed in basins scooped out for the purpose. The gravel thus washed is collected, spread out on a smooth piece of ground, and left to dry. The diamonds are now recognised by their sparkling in the sun, and are picked out from the stone.

Diamonds are also said to come from the interior of the island of Borneo, on the banks of the river Succadan, and from the peninsula of Malacca. It is said the principal spots where diamonds are found are recognised by certain small flints, generally of a black colour, which lie upon the surface, and also by the yellow colour of the stony soil. The ground is dug in the presence of an overseer: all stones above 5 carats, are claimed for the sovereign. Diamonds are found occasionally in the rivers, seldom however of any size.

The diamond mines of Brazil were discovered in 1728, in the district of Serro-do-Frio. The ground in which they are imbedded has the most perfect resemblance to that of the East Indies where the diamonds occur. It is a solid or friable conglomerate, consisting chiefly of a ferruginous sand, which encloses fragments of various magnitude of yellow and bluish quartz, of schistose, jasper, and grains of gold disseminated with oligist iron ore,—all mineral matters different from those that constitute the neighbouring mountains; this conglomerate, or species of pudding-stone, almost always superficial, occurs sometimes at a considerable height on the mountainous table-land. The most celebrated diamond mine is that of Mandarga, on the Jigitonhonha, in the district of Serro-do-Frio to the north of Rio-Janeiro. The river Jigitonhonha, three times broader than the Seine at Paris, and from 3 to 9 feet deep, is made nearly dry, by drawing the water off with sluices at a certain season; and the *cascalho*, or diamond gravel, is removed from the channel by various mechanical means, to be washed elsewhere at leisure. This cascalho, the same as the matrix of the gold mines, is collected in the dry season, to be searched into during the rainy; for which purpose it is formed into little mounds of 15 or 16 tons weight each. The washing is carried on beneath an oblong shed, by means of a stream of water admitted in determinate quantities into boxes containing the cascalho. A negro washer is attached to each box; inspectors are placed at regular distances on elevated stools, and whenever a negro has found a diamond, he rises up and exhibits it. If it weighs 17½ carats, he receives his liberty. Many precautions are taken to prevent the negroes from secreting the diamonds. Each squad of workmen consists of 200 negroes, with a surgeon and an almoner or priest,

The flat lands on either side of the river are equally rich in diamonds over their whole surface, so that it becomes very easy to estimate what a piece of groand not yet washed may produce.

It is said that the diamonds surrounded by a greenish crust are of the *first* water, or are the most limpid when cut. The diamonds received in the different mines of the district, are deposited once a month in the treasury of Tejuco; and the amount of what

was thus delivered from 1801 to 1806, may be estimated at about 18 or 19 thousand carats *per annum*.

On the banks of the torrent called Rio-Pardo, there is another mine of diamonds. The ground presents a great many friable rocks of pudding-stone, distributed in irregular strata. It is chiefly in the bed of this stream that masses of cascalho occur, peculiarly rich in diamonds. They are much esteemed, particularly those of a greenish-blue colour. The ores that accompany the diamond at Rio-Pardo differ somewhat from those of the washing grounds of Mandanga, for they contain no pisiform iron ore; but a great many pebbles of slaty jasper. This table land seems to be very high, probably not less than 5,500 feet above the level of the sea.

Tocaya, a principal village of Minas-Novas, is 34 leagues to the north-east of Tejuco, in an acute angle of the confluence of the Jigitonhonha and the Rio-Grande. In the bed of the streamlets which fall westward into the Jigitonhonha, those rolled white topazes are found which are known under the name of *minas novas* with *blue topazes*, and aquamarine beryls. In the same country are found the beautiful cymophanes or chrysoberyls so much prized in Brazil. And it is from the cantons of Indaia and Abaïte that the largest diamonds of Brazil come; yet they have not so pure a water as those of the district of Serro-do-Frio, but incline a little to the lemon yellow.

It is known that many minerals become phosphorescent by heat, or exposure to the sun's light. Diamonds, it has been said on doubtful authority, possess this property, but all not in equal degree, and certain precautions must be observed to make it manifest. Diamonds need to be exposed to the sunbeam for a certain time in order to become self-luminous; or to the blue rays of the prismatic spectrum, which augment still more the faculty of shining in the dark. Diamonds susceptible of phosphorescence exhibit it either after a heat not raised to redness, or the electric discharge. Many minerals possess the power of becoming electrically phosphorescent, which do not appear to be affected by the solar rays. Diamonds possess not only a great refractive power in the mean ray of light, but a high dispersive agency, which enables them to throw out the most varied and vivid colours in multiplied directions.

Diamonds take precedence of every gem for the purpose of dress and decoration; and hence the price attached to those of a pure water increases in so rapid a proportion, that, beyond a certain term, there is no rule of commercial valuation. The largest diamond that is known seems to be that of the Rajah of Mattan in the East Indies. It is of the purest water, and weighs 367 carats, or, at the rate of 4 grains to a carat, upwards of 3 ounces troy. It is shaped like an egg, with an indented hollow near the smaller end; it was discovered at Landak about 100 years ago; and though the possession of it has cost several wars, it remained in the Mattan family for 90 years. A governor of Batavia, after ascertaining the qualities of the gem, wished to be the purchaser, and offered 150,000 dollars for it, besides two war brigs with their guns and ammunition, together with a certain number of great guns, and a quantity of powder and shot. But this diamond possessed such celebrity in India, being regarded as a talisman involving the fortunes of the Rajah and his family, that he refused to part with it at any price.

The Mogul diamond passed into the possession of the ruling family of Kabul, as has been invariably affirmed by the members of that family, and by the jewellers of Delhi and Kabul. It has been by both parties identified with the great diamond now known under the name of the KOH-I-NOOR, or *mountain of light*, — which was displayed by its present proprietor, her Majesty the Queen, at the Great Exhibition in 1851.

The diamond denominated the Koh-i-noor, or Mountain (koh) of Light (noor), has long enjoyed both Indian and European celebrity, and has accordingly been the subject of traditionary fable, as well as of historical record.

According to Hindu legend, it was found in the mines of the south of India in the days of the Great War, the subject of the heroic poem, the *Maha'bha'rata*, and was worn by one of the warriors who was slain on that occasion, Karna, king of Anga: this would place it about 4000 years ago, or 2100 B.C. A long interval next makes it the property of Vikramaditya, the raja of Mjayin, 56 B.C., from whom it descended to his successors, the rajahs of Malwa, until the principality was subverted by Mohamedan conquerors, into whose hands it fell, with other spoils of infinite value.

Whatever may be thought of the legend which gives so high an antiquity to the Koh-i-Noor, we might expect some more trustworthy information when we come down so low as the beginning of the fourteenth century; Malwa having been invaded and overrun by the armies of Ala-ad-din, the sultan of Delhi, in 1306, who, according to the autobiography of the sultan Baber, acquired the jewel. That it did become the property of the sultanas of Delhi is little doubtful, but when or how is matter of some uncertainty, although the grounds of the difficulty have not hitherto been investigated.

In 1665 Mons. Jean Baptiste Tavernier, an enterprising and intelligent traveller, and an eminent jeweller, although Ecuyer, Baron d'Aubonne, visited India especially to purchase diamonds. His profession and his personal character seem to have recommended him to the favourable attention of the nobles of the court of Delhi, and bigot as he was, of Aurangzeb himself, by whose commands Mons. Tavernier was permitted to inspect, handle, and weigh the jewels of the imperial cabinet. Amongst them was one which far surpassed all the rest in size and value. Tavernier describes it as rose-cut, of the shape of an egg cut in two, of good water, and weighing 319½ *ratis*, which, he says, is equal to 280 of our carats.

There is but little doubt that the diamond examined by Tavernier in the Delhi Cabinet was the Koh-i-Noor. Babér, the Mogul emperor, obtained a diamond, corresponding exactly with this, and it passed eventually into the possession of the ruling family of Kabul. Nadir Shah, on his occupation of Delhi in 1739, compelled Mohammed Shah, the great-grandson of Aurangzeb, to give up to him everything of value that the imperial treasury possessed, and his biographer and secretary specifies a *peshkash*, or present, by Mohammed Shah to his conqueror of several magnificent diamonds. According to the family and popular tradition Mohammed Shah wore the Koh-i-Noor in front of his turban at his interview with his conqueror, who insisted on exchanging turbans in proof of his regard. However this might have been, we need have little doubt that the great diamond of Aurangzeb, was in the possession of Mohammed Shah at the time of the Persian invasion; and if it was, it most certainly changed masters, and became, as is universally asserted, the property of Nadir Shah, who is also said to have bestowed upon it the name of Koh-i-Noor. After his death, the diamond which he had wrested from the unfortunate representative of the house of Timur, became the property of Ahmed Shah, the founder of the Abdali dynasty of Kabul, having been given to him, or more probably taken by him, from Shahrikh, the young son of Nadir. The jewel descended to the successors of Ahmed Shah, and when Mr. Elphinstone was at Peshawur, was worn by Shah Shuja on his arm. When Shah Shuja was driven from Kabul, he became the nominal guest and actual prisoner of Runjet Sing, who spared neither importunity nor menace, until, in 1813, he compelled the fugitive monarch to resign the precious gem, presenting him on the occasion, it said, with a lakh and 25,000 rupees, or about 12,000*l.* sterling. According to Shah Shuja's own account, however, he assigned to him the revenues of three villages, not one rupee of which he ever realised. Runjet was highly elated by the acquisition of the diamond, and wore it as an armlet at all great festivals. When he was dying, an attempt was made by persons about him to persuade him to make the diamond a present to Jagannuth, and it is said that he intimated assent by an inclination of his head. The treasurer, however, whose charge it was, refused to give it up without better warrant, and Runjet dying before a written order could be signed by him, the Koh-i-Noor was preserved for awhile for his successors. It was occasionally worn by Rhurreuk Sing and Shu Sing. After the murder of the latter, it remained in the Lahore treasury until the supercession of Dhulip Sing, and the annexation of the Punjaub by the British Government, when the civil authorities took possession of the Lahore treasury, under the stipulations previously made, that all the property of the state should be confiscated to the East India Company, in part payment of the debt due by the Lahore government and of the expenses of the war; it was at the same time stipulated that the Koh-i-Noor should be presented to the Queen of England. Such is the strange history of certainly one of the most extraordinary diamonds in the world. After the Company became possessed of the gem, it was taken in charge by Lord Dalhousie, and sent by him to England in custody of two officers.—*Hunt's Handbook of the Great Exhibition of* 1851.

As exhibited at the Crystal Palace in Hyde Park, the Koh-i-Noor weighed 186$\frac{1}{16}$ carats.

The form of the Koh-i-Noor is given in *fig.* 644. P is a large plane at the base of the diamond which is a cleavage plane. F, also a large cleavage plane, produced by a fracture; this had not been polished, and being inclined to the plane P at an angle of 109° 28′, affords a satisfactory means for determining the direction of the cleavage planes of the stone. A shows a flaw running parallel to the cleavage plane F. This constituted the principal danger to be apprehended in cutting the stone, and was most skilfully ground nearly out before any of the facets were cut. This flaw seemed to proceed from a fracture marked B. C and E were little notches cut in the stone for the purpose of holding the diamond in its original setting; N a small flaw which almost required a glass to see it, evidently parallel to the plane P; D a fracture from a blow or fall, showing at its base a cleavage plane.—*Tennant.*

This fine diamond did not possess that high degree of brilliancy which was expected from its great reputation; it was consequently submitted to Messrs. Garrard to be recut. In the operation the weight was reduced more than one-third, but its brilliancy

was greatly improved. The present state of the Koh-i-Noor is shown in *figs.* 645 and 646. See DIAMOND-CUTTING.

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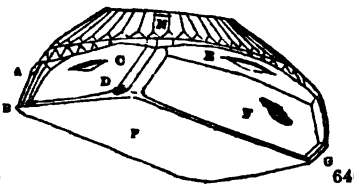

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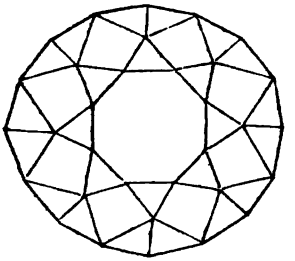

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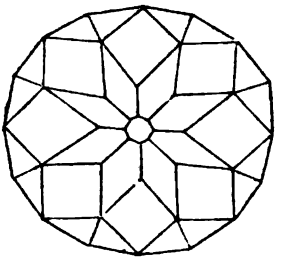


After this gem, the next are:—1. That of the emperor of Russia, bought by the late empress Catharine, which weighs 193 carats. It is said to be of the size of a pigeon's egg, and to have been bought for 90,000*l.*, besides an annuity to the Greek merchant of 4,000*l.* It is reported that the above diamond formed one of the eyes of the famous statue of Sherigan, in the temple of Brama, and that a French grenadier, who had deserted into the Malabar service, found the means of robbing the pagoda of this precious gem, and escaped with it to Madras, where he disposed of it to a ship captain for 2,000*l.*, who resold it to a Jew for 12,000*l.* From him it was transferred for a large sum to the Greek merchant. 2. That of the emperor of Austria, which weighs 139 carats, and has a slightly yellowish hue. It has, however, been valued at 100,000*l.* 3. That of the French State, called the Regent or Pitt diamond, remarkable for its form and its perfect limpidity. Although it weighs only 136 carats, its fine qualities have caused it to be valued at 160,000*l.*, though it cost only 100,000*l.*

The largest diamond furnished by Brazil, now in possession of the Crown of Portugal, weighs, according to the highest estimates, 120 carats. It was found in the streamlet of Abaïte, in a clay-slate district.

Diamonds possessed of no extraordinary magnitude, but of a good form and a pure water, may be valued by a certain standard rule. In a brilliant, or rose-diamond of regular proportions so much is cut away that the weight of the polished gem does not exceed one-half the weight of the diamond in the rough state; whence the value of a cut diamond is esteemed equal to that of a similar rough diamond of double weight exclusive of the cost of workmanship. The weight and value of diamonds is reckoned by carats of 4 grains each; and the comparative value of two diamonds of equal quality, but different weights, is as the squares of these weights respectively. The average price of rough diamonds that are worth working, is about 2*l.* for one of a single carat; but as a polished diamond of one carat must have taken one of two carats, its price in the rough state is double the square of 2*l.*, or 8*l.* Therefore to estimate the value of a wrought diamond, ascertain its weight in carats, double that weight, and multiply the square of this product by 2*l.* Hence, a wrought diamond of

1 carat	is worth	£8	7 carats	is worth	£392
2	„	32	8	„	512
3	„	72	9	„	612
4	„	128	10	„	800
5	„	200	20	„	3200
6	„	288			

beyond which weight the price can no longer rise in this geometrical progression, from the small number of purchasers of such expensive toys. A very trifling spot or flaw of any kind lowers exceedingly the commercial value of a diamond.

Diamonds are used not only as decorative gems, but for more useful purposes, as for cutting glass by the glazier, and all kinds of hard stones by the lapidary.

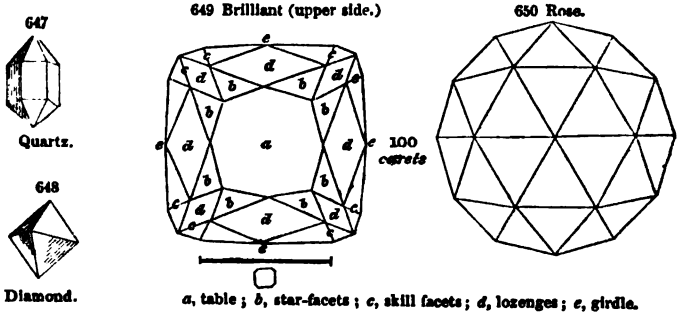
On the structure of the glazier's diamond we possess some very interesting observ-

ations and reflections by Dr. Wollaston. He remarks, that the hardest substances brought to a sharp point scratch glass, indeed, but do not cut it, and that diamonds alone possessed that property; which he ascribes to the peculiarity of its crystallisation in rounded faces, and curvilinear edges. For glass-cutting, those rough diamonds are always selected which are sharply crystallised, hence called diamond sparks; but cut diamonds are never used. The inclination to be given to a set diamond in cutting glass is comprised within very narrow limits; and it ought, moreover, to be moved in the direction of one of its angles. The curvilinear edge adjoining the curved faces, entering as a wedge into the furrow opened up by itself, thus tends to separate the parts of the glass; and in order that the crack which causes the separation of the vitreous particles may take place, the diamond must be held almost perpendicular to the surface of the glass. The Doctor proved this theory by an experiment. If, by suitable cutting with the wheel, we make the edges of a spinel ruby, or corundum-telesie (sapphire), curvilinear, and the adjacent faces curved, these stones will cut glass as well as a glazier's diamond, but being less hard than it, they will not preserve this property so long. He found that upon giving the surface of even a fragment of flint the same shape as that of the cutting diamond, it acquired the same property; but, from its relative softness, was of little duration. The depth to which the fissure caused by the glazier's diamond penetrates does not seem to exceed the two-hundredth of an inch.

The following remarks by Mr. Tennant cannot fail to be of interest, and, as pointing out the errors which have been frequently committed through ignorance, of great value.

"By attending to the forms of the crystal, we are quite sure that we shall not find the emerald, sapphire, zircon, or topaz in the form of a cube, octahedron, tetrahedron, or rhombic dodecahedron; nor the *diamond*, spinel, or garnet in that of a six sided prism, and so on with other gems. For want of a knowledge of the crystalline form of the diamond a gentleman in California offered 200*l.* for a small specimen of quartz. He knew nothing of the substance, except that it was a bright shining mineral, excessively hard, not to be scratched by the file, and which would scratch glass. Presuming that these qualities belonged only to the diamond, he conceived that he was offering a fair price for the gem; but the owner declined the offer. Had he known that the diamond was never found as a six-sided prism, terminated at each end by a six-sided pyramid, he would have been able to detect the fact that what he was offered 200*l.* for, was really not worth more than half a crown."—*Tennant's Lecture on Gems.*

The accompanying forms may serve to guide those who are ignorant of crystallography.



a, table; *b*, star-facets; *c*, skill facets; *d*, lozenges; *e*, girdle.

The following technical terms are applied to the different faces of diamonds:—

Bezils: the upper sides and corners of the *brilliant*, lying between the edge of the table and the girdle.

Collet: the small horizontal plane or face, at the bottom of the *brilliant*.

Crown: the upper work of the rose, which all centres in the point at the top, and is bounded by the horizontal ribs.

Facets: small triangular faces, or planes, both in *brilliants* and *roses*. In *brilliants* there are two sorts, *skew* or *skill*-facets, and *star*-facets. Skill-facets are divided into *upper* and *under*. Upper skill-facets are wrought on the lower part of the bezil, and terminate in the girdle; under-skill facets are wrought on the pavilions, and terminate in the girdle; star-facets are wrought on the upper part of the bezil and terminate in the table.

Girdle: the line which encompasses the stone parallel to the horizon; or, which determines the greatest horizontal expansion of the stone.

Lozenges: are common to *brilliants* and *roses*. In *brilliants* they are formed by the meeting of the skill and star-facets on the bezil. In *roses* by the meeting of the facets in the horizontal ribs of the crown.

Pavilions: the under sides and corners of *brilliants*, lying between the girdle and the collet.

Ribs: the lines, or ridges, which distinguish the several parts of the work, both in *brilliants* and *roses*.

Table: the large horizontal plane, or face, at the top of the *brilliant*.

Fig. 649 represents a brilliant, and *fig.* 650 a rose cut diamond.

The rose diamond is flat beneath, like all weak stones, while the upper face rises into a dome and is cut into facets. Most usually six facets are put on the central region which are in the form of triangles, and unite at their summits; their bases abut upon another range of triangles, which being set in an inverse position to the preceding, present their bases to them, while their summits terminate at the sharp margin of the stone. The latter triangles leave spaces between them which are likewise cut each into two facets. By this distribution the rose diamond is cut into 24 facets; the surface of the diamond being divided into two portions, of which the upper is called the crown, and that forming the contour, beneath the former, is called *dentelle* (lace) by the French artists.

According to Mr. Jefferies, in his Treatise on Diamonds, the regular rose diamond is formed by inscribing a regular octagon in the centre of the table side of the stone, and bordering it by eight right-angled triangles, the bases of which correspond with the sides of the octagon; beyond these is a chain of 8 trapeziums, and another of 16 triangles. The collet side also consists of a minute central octagon, from every angle of which proceeds a ray to the edge of the girdle, forming the whole surface into 8 trapeziums, each of which is again subdivided by a salient angle (whose apex touches the girdle) into one irregular pentagon and two triangles.

To fashion a rough diamond into a brilliant, the first step is to modify the faces of the original octahedron, so that the plane formed by the junction of the two pyramids shall be an exact square, and the axis of the crystal precisely twice the length of one of the sides of the square. The octahedron being thus rectified, a section is to be made parallel to the common base or *girdle*, so as to cut off 5 eighteenths of the whole height from the upper pyramid, and 1 eighteenth from the lower one. The superior and larger plane thus produced is called the *table*, and the inferior and smaller one is called the *collet;* in this state it is termed a *complete square table diamond*. To convert it into a brilliant, two triangular facets are placed on each side of the table, thus changing it from a square to an octagon; a lozenge-shaped facet is also placed at each of the four corners of the table, and another lozenge extending lengthwise along the whole of each side of the original square of the table, which with two triangular facets set on the base of each lozenge, completes the whole number of facets on the table side of the diamond; viz. 8 lozenges, and 24 triangles. On the collet side are formed 4 irregular pentagons, alternating with as many irregular lozenges radiating from the collet as a centre, and bordered by 16 triangular facets adjoining the girdle. The brilliant being thus completed, is set with the table side uppermost, and the collet side implanted in the cavity made to receive the diamond. The brilliant is always three times as thick as the rose diamond. In France, the thickness of the brilliant is set off into two unequal portions; one third is reserved for the upper part or table of the diamond, and the remaining two thirds for the lower part or collet (*culasse*). The table has eight planes, and its circumference is cut into facets, of which some are triangles and others lozenges. The collet is also cut into facets called *pavillons*. It is of consequence that the pavillons lie in the same order as the upper facets, and that they correspond to each other, so that the symmetry be perfect, for otherwise the play of the light would be false.

Although the rose-diamond projects bright beams of light in more extensive proportion often than the brilliant, yet the latter shows an incomparably greater play, from the difference of its cutting. In executing this, there are formed 32 faces of different figures, and inclined at different angles all round the table, on the upper side of the stone. On the *collet* (culasse) 24 other faces are made round a small table, which converts the culasse into a truncated pyramid. These 24 facets, like the 32 above, are differently inclined and present different figures. It is essential that the faces of the top and the bottom correspond together in sufficiently exact proportions to multiply the reflections and refractions, so as to produce the colours of the prismatic spectrum.

DIAMONDS, *cutting of.* Although the diamond is the hardest of all known substances, yet it may be split by a steel tool, provided a blow be applied; but this requires a perfect knowledge of the structure, because it will only yield to such means in certain directions. This circumstance prevents the workman from forming facettes or planes

generally, by the process of splitting; he is therefore obliged to resort to the process of abrasion, which is technically called cutting. The process of cutting is effected by fixing the diamond to be cut on the end of a stick, or handle, in a small ball of cement, that part which is to be reduced being left to project. Another diamond is also fixed in a similar manner; and the two stones being rubbed against each other with considerable force, they are mutually abraded, flat surfaces, or facettes, being thereby produced. Other facettes are formed by shifting the diamonds into fresh positions in the cement, and when a sufficient number are produced, they are fit for polishing. The stones, when cut, are fixed for this purpose, by imbedding them in soft solder, contained in a small copper cup, the part or facette to be polished being left to protrude,

A flat circular plate of cast-iron is then charged with the powder produced during the abrasion of the diamonds; and by this means a tool is formed which is capable of producing the exquisite lustre so much admired on a finely-polished gem. Those diamonds that are unfit for working on account of the imperfection of their lustre or colour, are sold, for various purposes, under the technical name of Bort. Stones of this kind are frequently broken in a steel mortar, by repeated blows, until they are reduced to a fine powder, which is used to charge metal plates of various kinds, for the use of jewellers, lapidaries, and others. Bort, in this state of preparation, is incapable of polishing any gems; but it is used to produce flat surfaces on rubies and other precious stones.

Fine drills are made of small splinters of bort, which are used for drilling small holes in rubies, and other hard stones, for the use of watch-jewellers, gold and silver wire-drawers, and others who require very fine holes drilled in such substances. These drills are also used to pierce holes in china, where rivets are to be inserted; also for piercing holes in artificial enamel teeth, or any vitreous substances, however hard.

The following description furnished to Mr. Tennant, by Messrs. Garrard, of the cutting of the Koh-i-noor will fully explain the peculiar conditions of the process, and also show that there are some remarkable differences in the physical condition of the gem in its different planes. The letters refer to the cut of the Koh-i-noor, article DIAMOND, *fig.* 644.

"In cutting diamonds from the rough, the process is so uncertain that the cutters think themselves fortunate in retaining one-half the original weight. The Koh-i-noor, on its arrival in England, was merely surface cut, no attempt having been made to produce the regular form of a brilliant by which alone lustre is obtained. By reference to the figures, which are the exact size of the Koh-i-noor, it will be clearly understood that it was necessary to remove a large portion of the stone in order to obtain the desired effect, by which means the apparent surface was increased rather than diminished, and the flaws and yellow tinge were removed.

"The process of diamond cutting is effected by an horizontal iron plate of about ten inches diameter, called a *schyf*, or *mill* which revolves from two thousand to three thousand times per minute. The diamond is fixed in a ball of pewter at the end of an arm, resting upon the table in which the plate revolves; the other end, at which the ball containing the diamond is fixed, is pressed upon the wheel by movable weights at the discretion of the workmen. The weight applied varies from 2 to 30 lbs. according to the size of the facets intended to be cut. The recutting of the Koh-i-noor was commenced on July 16, 1852, His Grace the late Duke of Wellington being the first person to place it on the mill; the portion first worked upon was that at which the planes P and P meet, as it was necessary to reduce the stone at that part, and so to level the set of the stone before the table could be formed; the intention being to turn the stone rather on one side, and take the incision or flaw at E, and a fracture on the other side of the stone, not shown in the engraving, as the boundaries or sides of the girdle. The next important step was the attempt to remove an incision or flaw at C, described by Professor Tennant and the Rev. W. Mitchell as having been made for the purpose of holding the stone more firmly in its setting, but pronounced by the cutters (after having cut into and examined it) to be a natural flaw of a yellow tinge, a defect often met with in small stones. The next step was cutting a facet on the top of the stone immediately above the last mentioned flaw. Here the difference in the hardness of the stone first manifested itself; for while cutting this facet, the lapidary noticing that the work did not proceed so fast as hitherto, allowed the diamond to remain on the mill rather longer than usual, without taking it off to cool; the consequence was, that the diamond became so hot from the continual friction and greater weight applied, that it melted the pewter in which it was imbedded. Again, while cutting the same facet, the mill became so hot from the extreme hardness of the stone, that particles of iron mixed with diamond powder and oil ignited. The probable cause of the diamond proving so hard at this part is, that the lapidary was obliged to cut directly upon the angle at which two cleavage planes meet, cutting across the grain of the stone. Another step that was thus considered to

be important by the cutters was removing a flaw at c. This flaw was not thought by Professor Tennant and Mr. Mitchell to be dangerous, because if it were allowed to run according to the cleavage, it would only take off a small piece, which it was necessary to remove in order to acquire the present shape. The cutters, however, had an idea that it might not take the desired direction, and, therefore, began to cut into it from both sides, and afterwards directly upon it, and thus they succeeded in getting rid of it. While cutting, the stone appeared to become harder and harder the further it was cut into, especially just above the flaw at A, which part became so hard, that, after working the mill at the medium rate of 2400 times per minute, for six hours, little impression had been made; the speed was therefore increased to more than 3000, at which rate the work gradually proceeded. When the back (or former top) of the stone was cut, it proved to be much softer, so that a facet was made in three hours, which would have occupied more than a day, if the hardness had been equal to that on the other side; nevertheless, the stone afterwards became gradually harder, especially underneath the flaw at A, which part was nearly as hard as that directly above it. The flaw at B did not interfere at all with the cutting. An attempt was made to cut out the flaw at A, but it was found not desirable on account of its length. The diamond was finished on September 7th, having taken thirty-eight days to cut, working twelve hours per day without cessation." The weight of the Koh-i-Noor since cutting is 162½ carats.

DIAMOND DUST. The use of diamond dust within a few years has increased very materially, on account of the increased demand for all articles that are wrought by it, such as cameos, intaglios, &c. There has been a discovery made of the peculiar power of diamond dust upon steel; it gives the finest edge to all kinds of cutlery, and it threatened at one time to displace the hone of Hungary. Finely powdered corundum, however, now occupies its place. It is well known that in cutting a diamond, the dust is placed on the teeth of the saw — to which it adheres; to this dust is to be attributed solely the power of man to make brilliants from rough diamonds. The dust enables the polisher to obtain the perfection of geometrical symmetry, which is one of the chief beauties of the mineral, and also that adamantine polish, which nothing can injure or affect, save a substance of its own nature.

Diamond dust, it would appear, can now be manufactured by the agency of voltaic electricity. See DIAMOND.

DIAMOND MICROSCOPES were first suggested by Dr. Goring, and have been well executed by Mr. Pritchard. Previous to grinding a diamond into a spherical figure, it should be ground flat and parallel upon both sides, that by looking through it, as opticians try flint glass, we may see whether it has a double or triple refractive power, as many have, which would render it useless as a lens. Among the different crystalline forms of the diamond, probably the octahedron and the cube are the only ones that will give a single vision. It will, in many cases, be advisable to grind diamond lenses plano-convex, both because this figure gives a low spherical aberration, and because it saves the trouble of grinding one side of the gem. A concave tool of cast iron, paved with diamond powder, hammered into it by a hardened steel punch, was employed by Mr. Pritchard. This ingenious artist succeeded in completing a double convex of equal radii, of about $\frac{1}{12}$ of an inch focus, bearing an aperture of $\frac{1}{30}$ of an inch with distinctness upon opaque objects, and its entire diameter upon transparent ones. This lens gives vision with a trifling chromatic aberration; in other respects, like Dr. Goring's Amician reflector, but without its darkness, its light is said to be superior to that of any compound microscope whatever, acting with the same power, and the same angle of aperture. The advantage of seeing an object without *aberration* by the interposition of only a single magnifier, instead of looking at a picture of it with an eye-glass, is evident. We thus have a simple direct view, whereby we shall see more accurately and minutely the real texture of objects.

DIAMOND TOOLS. 1. *The Glazier's diamond* is the natural diamond, so set that one of its edges is brought to bear on the glass.

The extreme point of any diamond will *scratch* glass, making a white streak; but when the rounded edge of a diamond is slid over a sheet of glass with but slight pressure, it produces *a cut*, which is scarcely visible, but which readily extends through the mass.

Dr. Wollaston succeeded in giving to the ruby, topaz, and rock crystal forms similar to those of the diamond, and with those he succeeded in *cutting* glass; proving that this useful property of the diamond depended on its form. Although the primitive form of the diamond is that of a regular octahedron, the Duke de Bournon has published upwards of one hundred forms of crystallisation of the diamond. The irregular octahedrons with round facets are those proper for glaziers' diamonds.

Notwithstanding the hardness of the diamond, yet, in large glass works, as many as one and two dozens are worn out every week: from being convex, they become rapidly concave, and the cutting power is lost.

2. *Diamond drills* are made of various shapes; these are either found amongst imperfect diamonds, or, are selected from fragments split off from good stones in their manufacture for jewelling.

DIAPER is the name of a kind of cloth, used chiefly for table linen. It is known among the French by the name of *toile fourré*, and is ornamented with the most extensive figures of any kind of tweeled cloth, excepting damask. The mounting of a loom for working diaper is, in principle, much the same as a draw-loom, but the figures being less extensive, the mounting is more simple, and is wrought entirely by the weaver, without the aid of any other person. As tweeled cloths, of any number of leaves, are only interwoven at those intervals when one of the leaves is raised, the woof above and the warp below are kept floating or flushed, until the intersection takes place. Of consequence the floating yarn above appears across the fabric, and that below longitudinally. This property of tweeled cloths is applied to form the ornamental figures of all kinds of tweeled goods, merely by reversing the floating yarn when necessary. In the simpler patterns, this is effected by a few additional leaves of treddles; but when the range of pattern becomes too great to render this convenient, an apparatus called a *back harness* is employed, and the cloth woven with this mounting is called diaper. Diapers are generally five-leaf tweels, that is to say, every warp floats under four threads of woof, and is raised, and of course interwoven with the fifth. This is done either successively, forming diagonals at 45° upon the cloth, or by intervals of two threads, which is called the broken tweel. The latter is generally, if not universally, adopted in the manufacture of diaper. The reason of preferring the broken to the regular tweel, where ornaments are to be formed, is very obvious. The whole depending upon reversed flushing, to give the appearance of oblique or diagonal lines through either, would destroy much of the effect, and materially injure the beauty of the fabric. The broken tweel, on the contrary, restores to the tweeled cloth a great similarity of appearance to plain or alternately interwoven fabrics, and at the same time preserves the facility of producing ornaments by reversing the flushing.

DIASTASE. A white and tasteless substance, obtained by moistening pounded malt, and squeezing the water through a bag. Albumen is precipitated from the turbid fluid by alcohol, and filtered. Then the diastase is precipitated by an additional quantity of alcohol, and purified by re-solution and re-precipitation. One part of diastase will convert 2000 parts of starch into dextrine, and 1000 parts into sugar.

DICHROISM. The property of exhibiting two colours. Many of the phenomena belong to the conditions producing FLUORESCENCE, which see. Some of the phenomena have been referred to polarisation, but this requires examination.

DIDYMIUM (Di). A metal discovered by Mosandar, in 1841, in *oxide of cerium*, and so called as being associated in that ore as a twin brother with *lanthanum*.

The oxide of Didymium (DiO) is a dark brown powder; the salts are pink, or rose, and amethyst or violet.

DIES FOR STAMPING. (*Coins*, Fr.; *Münzstampeln*, Germ.) The first circumstance that claims particular attention in the manufacture of dies, is the selection of the best kind of steel for the purpose, and this must in some measure be left to the experience of the die-forger, who, if well skilled in his art, will be able to form a tolerably correct judgment of the fitness of the metal for the purpose, by the manner in which it works upon the anvil. It should be rather fine-grained than otherwise, and above all things perfectly even and uniform in its texture, and free from spots and patches finer or coarser than the general mass. But the very fine and uniform steel with a silky fracture, which is so much esteemed for some of the purposes of cutlery, is unfit for our present purpose, from the extreme facility with which it acquires great hardness by pressure, and its liability to cracks and flaws. The very cross-grained, or highly crystalline steel, is also equally objectionable; it acquires fissures under the die-press, and seldom admits of being equally and properly hardened. The object, therefore, is to select a steel of a medium quality as to fineness of texture, not easily acted upon by dilute sulphuric acid, and exhibiting an uniform texture when its surface is washed over with a little aquafortis, by which its freedom from pins of iron, and other irregularities of composition, is sufficiently indicated.

The best kind of steel being thus selected, and properly forged at a high heat into the rough die, it is softened by very careful annealing, and in that state, having been smoothed externally, and brought to a table in the turning lathe, it is delivered to the engraver.

The process of annealing the die consists in heating it to a bright cherry red, and suffering it to cool gradually, which is best effected by bedding it in a crucible or iron pot of coarsely-powdered charcoal. In this operation it is sometimes supposed that the die, or at least its superficial parts, becomes super-carbonised, or highly converted steel, as it is sometimes called; but experience does not justify such an opinion, and I believe the composition of the die is scarcely, certainly not

materially, affected by the process, for it does not remain long enough in the fire for the purpose.

The engraver usually commences his labours by working out the device with small steel tools in intaglio; he rarely begins in relief (though this is sometimes done); and having ultimately completed his design, and satisfied himself of its general effect and correctness, by impressions in clay, and dabs, or casts in type metal, the die is ready for the important operation of hardening, which, from various causes, a few of which I shall enumerate, is a process of much risk and difficulty; for should any accident now occur, the labour of many months may be seriously injured, or even rendered quite useless.

The process of hardening soft steel is in itself very simple, though not very easily explained upon mechanical or chemical principles. We know by experience, that it is a property of this highly valuable substance to become excessively hard, if heated and suddenly cooled; if, therefore, we heat a bar of soft malleable and ductile steel red hot, and then suddenly quench it in a large quantity of cold water, it not only becomes hard, but fragile and brittle. But as a die is a mass of steel of considerable dimensions, this hardening is an operation attended by many and peculiar difficulties, more especially as we have at the same time to attend to the careful preservation of the engraving. This is effected by covering the engraved face of the die with a protecting face, composed of fixed oil of any kind, thickened with animal charcoal: some persons add pipe-clay, others use a pulp of garlic, but pure lamp-black and linseed oil answer the purpose perfectly. This is thinly spread upon the work of the die, which, if requisite, may be further defended by an iron ring; the die is then placed with its face downwards in a crucible, and completely surrounded by animal charcoal. It is heated to a suitable temperature, that is, about cherry red, and in that state is taken out with proper tongs, and plunged into a body of cold water, of such magnitude as not to become materially increased in temperature; here it is rapidly moved about, until all noise ceases, and then left in the water till quite cool. In this process it should produce a bubbling and hissing noise; if it pipes and sings, we may generally apprehend a crack or fissure.

No process has been found to answer better than the above simple and common mode of hardening dies, though others have had repeated and fair trials. It has been proposed to keep up currents and eddies of cold water in the hardening cistern, by means of delivery-pipes, coming from a height; and to subject the hot die, with its face uppermost, to a sudden and copious current of water, let fall upon it from a large pipe, supplied from a high reservoir; but these means have not in any way proved more successful, either in saving the die, or in giving it any good qualities. It will be recollected, from the form of the die, that it is necessarily only, as it were, case-hardened, the hardest strata being outside, and the softer ones within, which envelope a core, something in the manner of the successive coats of an onion; an arrangement which we sometimes have an opportunity of seeing displayed in dies which have been smashed by a violent blow.

The hardening having been effected, and the die being for the time safe, some further steps may be taken for its protection; one of these consists in a very mild kind of tempering, produced by putting it into water, gradually raised to the boiling point, till heated throughout, and then suffering it gradually to cool. This operation renders the die less apt to crack in very cold weather. A great safeguard is also obtained by thrusting the cold die into a red-hot iron ring, which just fits it in that state, and which, by contracting as it cools, keeps its parts together under considerable pressure, preventing the spreading of external cracks and fissures, and often enabling us to employ a split or die for obtaining punches, which would break to pieces without the protecting ring.

If the die has been successfully hardened, and the protecting paste has done its duty by preserving the face from all injury and oxidisement, or burning, as it is usually called, it is now to be cleaned and polished, and in this state constitutes what is technically called a MATRIX; it may of course be used as a multiplier of medals, coins, or impressions, but it is not generally thus employed, for fear of accidents happening to it in the coining press, and because the artist has seldom perfected his work upon it in this state. It is, therefore, resorted to for the purpose of furnishing a PUNCH, or steel impression for relief. For this purpose a proper block of steel is selected, of the same quality, and with the same precautions as before, and being carefully annealed, or softened, is turned like the matrix, perfectly true and flat at the bottom, and obtusely conical at top. In this state, its conical surface is carefully compressed by powerful and proper machinery upon the matrix, which, being very hard, soon allows it to receive the commencement of an impression; but in thus receiving the impression, it becomes itself so hard by condensation of texture as to require during the operation to be repeatedly annealed, or softened, otherwise it would split into small

superficial fissures, or would injure the matrix; much practical skill is therefore required in taking the impression, and the punch, at each annealing, must be carefully protected, so that the work may not be injured.

Thus, after repeated blows in the die-press, and frequent annealing, the impression from the matrix is at length perfected, or brought completely up, and having been retouched by the engraver, is turned, hardened, and collared, like the matrix, of which it is now a complete impression in relief, and, as we have before said, is called a punch.

This punch becomes an inexhaustible parent of dies, without further reference to the original matrix; for now by impressing upon it plugs of soft steel, and by pursuing with them an exactly similar operation to that by which the punch itself was obtained, we procure impressions from it to any amount, which, of course are fac-similes of the matrix, and these dies being turned, hardened, polished, and, if necessary, tempered, are employed for the purposes of coinage.

The distinction between striking medals and common coin is very essential, and the work upon the dies is accordingly adjusted to each. Medals are usually in very high relief, and the effect is produced by a succession of blows; and as the metal in which they are struck, be it gold, silver, or copper, acquires considerable hardness at each stroke of the press, they are repeatedly annealed during the process of bringing them up. In a beautiful medal, which Mr. Wyon executed for the Royal Naval College, the obverse represents the head of the King, in very bold relief; it required thirty blows of a very powerful press to complete the impression, and it was necessary to anneal each medal after every third blow, so that they went ten times into the fire for that purpose. In striking a coin or medal, the lateral spread of the metal, which otherwise would ooze out as it were from between the dies, is prevented by the application of a steel collar, accurately turned to the dimensions of the dies, and which, when left plain, gives to the edge of the piece a finished and polished appearance; it is sometimes grooved, or milled, or otherwise ornamented, and occasionally lettered, in which case it is made in three separate and movable pieces, confined by a ring, into which they are most accurately fitted, and so adjusted that the metal may be forced into the letters by its lateral spread, at the same time that the coin receives the blow of the screw-press.

Coins are generally completed by one blow of the coining-press. These presses are worked in the Royal Mint by machinery, so contrived that they shall strike, upon an average, sixty blows in a minute; the blank piece, previously properly prepared and annealed, being placed between the dies by part of the same mechanism.

The number of pieces which may be struck by a pair of dies of good steel, properly hardened and duly tempered, not unfrequently amounts at the Mint to between one and two hundred thousand; but the average consumption of dies is of course much greater, owing to the variable qualities of steel, and to the casualties to which the dies are liable; thus, the upper and lower die are sometimes struck together, owing to an error in the layer-on, or in that part of the machinery which ought to put the blank into its place, but which now and then fails so to do. This accident very commonly arises from the boy who superintends the press neglecting to feed the hopper of the layer-on with blank pieces. If a die is too hard, it is apt to break or split, and is especially subject to fissures, which run from letter to letter upon the edge. If too soft, it swells, and the collar will not rise and fall upon it, or it sinks in the centre, and the work becomes distorted and faulty. He, therefore, who supplies the dies for an extensive coinage, has many accidents and difficulties to encounter. There are eight presses at the Mint, frequently at work for ten hours each day, and the destruction of eight pair of dies per day (one pair for each press) may be considered a fair average result, though they much more frequently fall short of, than exceed this proportion. It must be remembered, that each press produces 3600 pieces per hour; but making allowance for occasional stoppages, we may reckon the daily produce of each press at 30,000 pieces; the eight presses, therefore, will furnish a diurnal average of 240,000 pieces.

DIES, hardening of. See STEEL, hardening of.

DIGESTER is the name of a copper kettle or pot of small dimensions, made very strong, and mounted with a safety valve in its top. Papin, the contriver of this apparatus, used it for subjecting bones, cartilages, &c. to the solvent action of high-pressure steam, or highly heated water, whereby he proposed to facilitate their digestion in the stomach. This contrivance is the origin of the French cookery pans, called *autoclaves*, because the lid is self-keyed, or becomes steam-tight by turning it round under clamps or ears at the sides, having been previously ground with emery to fit the edge of the pot exactly. In some autoclaves the lid is merely laid on with a fillet of linen as a lute, and then secured in its place by means of a screw bearing down upon its centre from an arched bar above. The safety valve is loaded either by a weight placed vertically upon it, or by a lever of the second kind pressing near its fulcrum,

and acted upon by a weight which may be made to bear upon any point of its graduated arm.

Chevreul has made a useful application of the digester to vegetable analysis. His instrument consists of a strong copper cylinder, into which enters a tight cylinder of silver, having its edge turned over at right angles to the axis of the cylinder, so as to form the rim of the digester. A segment of a copper sphere, also lined with silver, stops the aperture of the silver cylinder, being applied closely to its rim. It has a conical valve pressed with a spiral spring, of any desired force, estimated by a steel-yard. This spring is enclosed within a brass box perforated with four holes; which may be screwed into a tapped orifice in the top the digester. A tube screwed into another hole serves to conduct away the condensible vapours at pleasure into a Woulfe's apparatus.

DIKE or DYKE. A wall like division in rocks, produced by the ejection of trapean matter in a fused state from below, through the overlying strata. In many places those hard trap rocks stand out above the adjacent rocks, which have been worn away, presenting actually the appearance of a massive wall.

DILATATION. The increase of size produced in bodies by the agency of heat. See EXPANSION.

DILUVIUM. (*Diluvium.*) Deluge. Those accumulations of gravel and loose materials, which, by some geologists, are said to have been produced by the action of a diluvian wave or deluge, sweeping over the surface of the earth.—*Lyell.*

DIMITY is a kind of cloth cotton originally imported from India, and now manufactured in great quantities in various parts of Britain, especially in Lancashire. Dr. Johnson calls it *dimmity*, and describes it as a kind of fustian. The distinction between fustian and dimity seems to be, that the former designates a common tweeled cotton cloth of a stout fabric, which receives no ornament in the loom, but is most frequently dyed after being woven. Dimity is also a stout cotton cloth, but not usually of so thick a texture; and is ornamented in the loom, either with raised stripes or fancy figures: it is seldom dyed, but usually employed white, as for bed and bed-room furniture. The striped dimities are the most common, they require less labour in weaving than the others; and the mounting of the loom being more simple, and consequently less expensive, they can be sold at much lower rates.

DIOPTRIC LIGHTHOUSES. See LIGHTHOUSES.

DIORITES. A trap or greenstone rock, in which *albite* replaces *orthoclase.* Diorites are abundant in the Vosges.

DIP. When any stratum, mineral vein, or dike, does not lie horizontally it is said tod ip E. W. N. or S., as the case may be. The angle which it makes with the horizon is called the angle of the dip.

DIPPEL'S ANIMAL OIL. A fetid volatile oil obtained when animal substances, such as bone, are subjected to distillation. That which is found in commerce is obtained in the manufacture of bone-black.

DIPPING. Ornamental works in brass are usually brightened by a process called *dipping.* After the work has been properly fitted together and the grease removed, either by the action of heat, or by boiling in a pearl ash lye, it is *pickled* in a bath of dilute aqua fortis. It is then scoured bright with sand and water, and being well washed is plunged into the dipping bath, which consists of pure nitrous acid, commonly known as *dipping aqua fortis*, for an instant only, and is then well washed with cold and hot water to remove every trace of acid from the surface, after which the work is put into dry beech or box wood, sawdust, &c., well rubbed until it is quite dry, and then burnished and lackered with as little delay as possible.

DISINFECTANT. A substance which removes the putrid or infected condition of bodies. It is well not to confound it with antiseptic, which applies to those bodies which prevent putrefaction. The word disinfectant has lately become somewhat uncertain in its meaning, on account of a word being used as its equivalent, viz. deodoriser. This latter means a substance which removes odours. In reality, however, there are no such substances known to us as a class. There are, of course, some substances which destroy certain others having an odour, but in all cases the removal of the smell and the destruction or neutralisation of the body must be simultaneous. There is, however, a large class of substances that destroy putrefaction, and the name disinfectant is therefore distinctly needed. The gases which rise from putrefying bodies are not all capable of being perceived by the senses in their ordinary condition, but sometimes they are perceived. A disinfectant puts a stop to them and deodorises simultaneously. If any substance were to remove the smell of these gases, it would remove the gases too, as they are inseparable from their property of affecting the nose. A deodoriser would therefore be, and is, a disinfectant of that gas the smell of which it removes. But it has been suggested that it may remove those gases which smell, and allow the most deleterious to pass, they having no smell. Whenever we find such a class of substances, it will be well to give them

the name of deodorisers. There may be some truth in the hypothesis that metallic salts remove the sulphur, and by preventing the escape of sulphuretted hydrogen cause less odour, without complete disinfection. But it appears that the decomposition is a prevention of putrefaction in proportion to the removal of that gas in cases where it is given out, and it is quite certain that metallic solutions have disinfecting properties. Any solution having the effect here supposed would at the least be a partial disinfectant, inasmuch as the decomposition would be so far put a stop to, as to prevent at least one obnoxious gas. How the others could remain unacted on in this case it is difficult to comprehend. To prevent the formation of one gas is to arrest decomposition or to alter the whole character of the change which is producing the gases. The most deleterious of emanations have no smell at all to the ordinary senses, and we can only judge of the evil by its results, or the fact that the substances capable of producing it are near, or by the analysis of the air. (See SANITARY ARRANGEMENTS.) The cases where sulphuretted hydrogen accompanies the offensive matter, are chiefly connected with fæcal decomposition. This gas is a useful indication of the presence of other substances. So far as is known, the destruction of the one causes the destruction of the other. But the presence of sulphuretted hydrogen is no proof of the presence of infectious matter, nor is its absence a proof of the absence of infectious matter, it being only an occasional accompaniment. When the infectious matter and the odoriferous matter are one, as in the case, as far as we know, of putrid flesh, &c., then to deodorise is to disinfect. We can find then no line of duty to be performed by deodorisers, and no class of bodies that can bear the name, although there may be a few cases where the word may be found convenient. If, for example, we destroy one smell by superadding a greater, that might in one sense be a deodorising. If we added an acid metallic salt, and removed the sulphuretted hydrogen, letting loose those organic vapours which for awhile accompany this act, we might, to those who were not very near, completely destroy smell, and still send a substance into the air by no means wholesome; but in such a case decomposition is stopped, at least for a while. The smelling stage is by no means the most dangerous, nor has the use of the word *deodorise* any relation to sanitary matters, except in the grossest sense; it is desirable that persons should look far beyond the mere indications furnished by the nose, and as in science we can find no deodorisers, so in practice we need not look for any in the sense usually given to the word. The word may be used for such substances as remove the odour and the putrefaction of the moment, but allow them to begin again. Even in this case deodorisers become temporary disinfectants, which character all removers of smell must more or less have.

Antiseptics, or colytic agents. Substances which prevent decomposition. The words *colysis* and *colytic* come from κωλυω, to *arrest, restrain, cut short.* This word was proposed by the writer to apply to cases such as are included under antiseptics, antiferments, and similar words. There was needed a word for the general idea. A colytic force manifests itself towards living persons in anæsthetics, anodynes, and narcotics, as well probably, as in other ways. Colytics may probably act from different causes, but these causes not being separately distinguished, a name for the whole class can alone be given. The action of *colysis* is entirely opposed to *catalysis*, which is a loosening up of a compound. *Colysis* arrests *catalysis*, as well also as other processes of decomposition, ordinary oxidation for example. Disinfectants, in their character of restraining further decomposition, are included under *colytics.* One of the most remarkable substances for arresting decomposition is kreasote. It has been used in some condition or mixture from the earliest times. The ancient oil of cedar has been called with good reason turpentine, which has strong disinfecting properties, but the word has evidently been used in many senses, as there are many liquids to be obtained from cedar. It is used for the first liquid from the distillation of wood; and Berzelius for that reason says that the Egyptians used the pyroligneous acid, which, containing some kreasote, was a great antiseptic. But a mixture of this acid with soda would be of little value in embalming, nor is it probable that they would add a volatile liquid like turpentine along with caustic soda. It is expressly said (in Pliny) that the pitch was reboiled, or, in other words, the tar was boiled and distilled, the product being collected in the wool of fleeces, from which again it was removed by pressure. In doing this the light oils or naphtha would be evaporated, and the heavy oil of tar, containing the carbolic acid, or kreasote, would remain. It was called picenum, as if made of pitch or pissenum, and pisselæum or pitch oil, a more appropriate name than that of Runge's carbolic acid or coal-oil, and still more appropriate than the most recent, which, by following up a theory, has converted it into phenic acid. The distillation was made in copper vessels, and must have been carried very far, as they obtained "a reddish pitch, very clammy, and much fatter than other pitch." This was the *anthracene, chrysene,* and *pyrene* of modern chemistry. The remaining hard pitch was called *palimpissa*, or second pitch, which we call pitch in contradistinction

to tar. By the second pitch, however, was sometimes meant the product of distillation instead of what was left in the still. Some confusion therefore exists in the names, but not more than with us. The pitch oil was resinous fat, and of yellow colour, according to some. This oil, containing kreasote, was used for toothache — a colytic action applied to living bodies — and for skin diseases of cattle, for which it is found valuable. They also used it for preserving hams.—("*Disinfectants*," *by the Writer. Jour. Soc. of Arts*, 1857.)

It is quite possible that kreasote may be the chief agent in most empyreumatic substances which act as antiseptics. But it is not the only agent. Hydrocarbons of various kinds act as antiseptics, as well as alcohol and methylic alcohol, which contain little oxygen. To this class belong essential oils and substances termed perfumes, which are used for fumigation, and have also a powerful colytic action. It is exceedingly probable that the true theory of this action is connected with the want of oxygen. These substances do not rapidly oxidise, but, on the contrary, only very slowly, and that chiefly by the aid of other bodies. Their atoms are, therefore, in a state of tension, ready to unite when assisted. As an example, carbolic acid and kreasote unite with oxygen when a base is present, and form rosolic acid. We can scarcely suppose that an explanation, commonly resorted to in the case of sulphurous acid, would suit them; viz., that it takes up the oxygen, and so keeps it from the putrescible substance. It is, therefore, much more likely that its condition acts on the putrescible body. For, as the state of motion of a putrefying substance is transferred to another, so is the state of immobility.

In 1750 Sir John Pringle wrote his "Experiments on Septic and Antiseptic Substances, with remarks relating to their Use in the Theory of Medicine." He recommended salts of various kinds, and astringent and gummy parts of vegetables and fermenting liquors. Dr. Macbride followed him with numerous experiments. He speaks of acids being the long prescribed agents as antiseptics. He found them antiseptic even when diluted to a great extent. Alkalies also he found antiseptic, and salts in general. Also "gum-resins, such as myrrh, asafœtida, aloes, and terra japonica," besides "decoctions of Virginia snake-root, pepper, ginger, saffron, contrayerva root, sage, valerian root, and rhubarb, with mint, angelica, senna, and common wormwood." Many of the common vegetables also were included as to some extent antiseptic; such as horse-radish, mustard, carrots, turnips, garlic, onions, celery, cabbage, colewort. Lime was found to prevent, but not to remove putrefaction. We are inclined at present very much to qualify some of these observations. Animal fluids, he observes, will remain for a long time without putridity if kept from the air. He says that astringent mineral acids and ardent spirits "not only absorb the matter from the putrescent substances, but likewise crisp up its fibres, and thereby render it so hard and durable that no change of combination will take place for many years." He adds also molasses to the antiseptics. In 1767 the academy of Dijon gave a prize for the use of nitrate of potash in ventilation. This may have given the first idea to Carmichael Smyth. Guyton-Morveau came later with a volume of valuable experients on acids.

An *antiseptic* preserves from putrefaction, but does not necessarily remove the odour caused by that which has previously putrefied. Many of the substances described as disinfectants here, might equally be called antiseptics. When they remove the putrid matter they are disinfectants, when they prevent decomposition they are antiseptics. But when the smell is removed by a substance which is known to destroy putrefactive decomposition, and to preserve organic matter entire, then we have the most thorough disinfection; then we know that the removal of the smell is merely an indication of the removal of the evil.

Disinfectants are of various kinds. Nature seems to use soil as one of the most active. All the dejecta of the animals on the surface of the earth fall on the soil, and are rapidly made perfectly innoxious. Absorption distinguishes porous bodies, and the soil has peculiar facilities for the purpose. But if saturated, it could disinfect no longer. This is not allowed to occur; the soil absorbs air also, and oxidises the organic matter which it has received into its pores, and the offensive matter is by this means either converted into food for plants, or is made an innocent ingredient of the air, or, if the weather be moist, of the water. The air is therefore, in conjunction with the soil, one of the greatest disinfectants, but it acts also quite alone and independent of the soil. Its power of oxidising must be very great. The amount of organic effluvium sent into large towns is remarkable, and yet it seldom accumulates so as to be strongly perceptible to the senses. The air oxidises it almost as rapidly as it rises; this is hastened apparently by the peculiar agent in the air, ozone, which has a greater capacity of oxidation than the common air; when this is exhausted it is highly probable that the oxidation will be much slower, and this exhaustion does take place in a very short time. So rapid is the oxidation, that the wind, even

blowing at the rate of about fifteen to twenty miles an hour, is entirely deprived of its ozone by passing over less than a mile of Manchester. In London this does not take place so rapidly, at least near the Thames. But when the ozone is removed, it is probable that the rate of increase of the organic matter will be much greater. We may by this means, then, readily gauge the condition of a town up to a certain point by the removal of the ozone: but it requires another agent to gauge it afterwards or thoroughly. It is in connection with each other that the air and the soil best disinfect. When manure is thrown upon land without mixing with the soil, it may require a very long period to obtain thorough disinfection, but when the atmosphere is moist, or rain falls, then the air is rapidly transferred into every portion of the porous earth, and the organic matter becomes rapidly oxidised. To prevent a smell of manure, and with it also the loss of ammonia, it is then needful that as soon as possible the manure should be mixed with the soil. The same power of oxidation is common to all porous bodies, to charcoal, and especially, as Dr. Stenhouse has shown, to platinised charcoal. Disinfection by the use of porous bodies is not a process of preservation, but of slow destruction. It is an oxidation in which all the escaping gases are so thoroughly oxidised, that none of them have any smell or any offensive property. But being so, the body disinfected must necessarily decay, and in reality the process of decay is remarkably increased. All such bodies must therefore be avoided when manures are to be disinfected, as the valuable ingredients are destroyed instead of being preserved. Stenhouse has employed charcoal for disinfecting the air. The air is passed through the charcoal either on a large scale for a hospital or on a small scale as a respirator for the mouth. Care must be taken, however, to keep the charcoal dry: wet charcoal is not capable of absorbing air until that air is dissolved in the water. This solution takes place less rapidly in water. Wet charcoal is therefore a filter for fluids chiefly, and dry charcoal for vapours. Its destructive action on manures will, however, always prevent charcoal from being much used as a disinfectant for such purposes, or, indeed, any other substance which acts principally by its porosity or by oxidation. This the soil does only partially, as it has another power, viz. that of retaining organic substances fit to be the food of plants. Although air acts partly in conjunction with the soil and the rain to cause disinfection, and partly by its own power, it also acts mechanically as a means of removing all noxious vapours. The wind and other currents of the air are continually ventilating the ground, and when these movements are not sufficiently rapid, or when they are interrupted by our mode of building, we are compelled to cause them artificially, and thus we arrive at the art of ventilation. The addition of one tenth of a per cent. of carbonic acid to the air may be perceived, at least if accompanied with the amount of organic matter usually given out at the same time in the breath, and as we exhale in a day 20 cubic feet of carbonic acid, we can injure the quality of 20,000 cubic feet of air in that time. The great value of a constant change of air is therefore readily proved, and the instinctive love which we have of fresh air is a sufficient corroboration.

Cold is a great natural disinfectant. The flesh of animals may be preserved as far as we know for thousands of years in ice; putrefying emanations are completely arrested by freezing, but the mobility of the particles, or chemical action, is also retarded by a degree of cold much less than freezing.

Heat is also a disinfectant, when it rises to about 140° of Fahrenheit, according to Dr. Henry. But as a means of producing dryness it is a disinfectant at various temperatures. Nothing which is perfectly dry can undergo putrefaction. On the other hand heat with moisture below 140° is a condition very highly productive of decomposition and all its resulting evils. Disinfection by heat is used at quarantine stations. Light is undoubtedly a great disinfectant; so far as we know, it acts by hastening chemical decomposition. In all cases of ventilation, it is essential to allow the rays of light to enter with the currents of air. Its effect on the vitality of the human being is abundantly proved, and is continually asserting itself in vegetation. The true disinfecting property of light exists in all probability in the chemical rays which cause compositions and decompositions. Water, however, is of all natural disinfectants the most manageable, and there is no one capable of taking its place actively. Wherever animals even human beings, live, there are emanations of organic matter, even from the purest. The whole surface of the house, furniture, floor, and walls, becomes coated by degrees with a thin covering, and this gradually decomposes, and gives off unpleasant vapours. Sometimes it becomes planted with fungi, and so feeds plants of this kind. But long before this occurs a small amount of vapour is given off sufficiently disagreeable to affect the senses, and sometimes affecting the spirits and the health before the senses distinctly perceive it. This must be removed. In most cases this film is removed by water, and we have the ordinary result of household cleanliness; but in other cases when the furniture is such as will be injured by water, the removal is made by friction or by oil or turpentine, and other substances used to polish. Water as a disinfectant

is used also in washing of clothes, for this purpose nothing whatever can supply its place, although it requires the assistance both of soap and friction, or agitation and heat. Water is also used as a mechanical agent for removing filth, and the method which Hercules devised of using a river to wash away filth, is now adopted in all the most advanced plans of cleansing towns. It is only by means of water that the refuse of towns can be conveyed away in covered and impervious passages, whilst none whatever is allowed to remain in the town itself. In cases where this cannot be done, it is much to be desired that some disinfecting agent should be used to prevent decomposition. Where water is not used, as in water-closets, there must of course be a great amount of matter stored up in middens, and the town is of course continually exposed to the effluvia. Besides these methods of acting, water disinfects partly by preventing effluvia from arising from bodies, simply because it keeps them in solution. This action is not a perfect one, but one of great value. The water gives off the impurity slowly, sometimes so slowly as to be of no injury, or it keeps it so long that complete oxidation takes place. The oxygen for this purpose is supplied by the air, which the water absorbs without ceasing. To act in this way, water must be delivered in abundance; when only existing as a moisture, water may act as a great opponent to disinfection by rising up in vapour loaded with the products of decomposition.

Mere drying is known to arrest decay, as the mobility of the particles in decomposition is stayed by the want of water. We are told in Andersson's travels in S. Africa, that the Damaras cut their meat into strips, and dry it in the sun, by which means it is preserved fresh. A similar custom is found in S. America. Certain days prevent this, and decomposition sets in rapidly. A little overclouding of the sky, or a little more moisture in the air, quickly stops the process.

The above may be called natural disinfectants, or imitations of natural processes, charcoal being introduced as an example of a more decided character of porous action. They show both mechanical and chemical action. The mechanical, when water or air removes, dilutes, or covers the septic bodies: the chemical, when porous bodies act as conveyers of oxygen: or an union of both, when cold and heat prevent the mobility of the particles. The action by oxidation causes a destruction of the offensive material. The other method is antiseptic. It is much to be desired that all impurities should be got rid of by some of these methods, but especially by the air, the water, and the soil. There are, however, conditions in which difficulties interfere with the action. Large towns may be purified by water, but what is to be done with the water which contains all the impurity? If put upon land, it is very soon disinfected, but on its way to the land it may do much mischief. It has been proposed to disinfect it on its passage, and even in the sewers themselves; by this means the town itself is freed from the nuisance, and the water may be used where it is needed without fear. This introduces artificial disinfectants. There are other cases where such are required; when the refuse matter of a town is allowed to lie either in exposed or in underground receptacles; in this case a town is exposed to an immense surface of impurity, and disinfectants would greatly diminish the evil, if not entirely remove it. There are besides, special cases without end continually occurring, where impurities cannot be at once removed, and where treatment with artificial disinfectants is required.

Artificial disinfectants which destroy the compound, are of various kinds. *Fire* is one of the most powerful. A putrid body, when heated so as to be deprived of all volatile particles, cannot any longer decompose. It is however possible that the vapours may become putrid, and if not carefully treated, this will happen. It was the custom of some of the wealthy among the ancients to burn the dead, and it is still the custom in India; but although the form is kept up amongst all classes, the expense is too great for the poor. The bodies are singed, or even less touched by fire, and thrown if possible into the river. This process has been recommended here, but the quality of the gaseous matter rising from a dead body, is most disgusting to our physical, and still more to our moral senses, and the amount is enormous. It is of course possible so to burn it, that only pure carbonic acid, water, and nitrogen, shall escape, but the probability of preventing all escape is small enough to be deemed an impossibility, and the escape of one per cent. would cause a rising of the whole neighbourhood. To effect the combustion of the dead of a great city, such a large work, furnished with great and powerful furnaces, would be required, that it would add one of the most frightful blots to modern civilisation, instead of the calm and peaceful churchyard where our bones are preserved as long at least as those who care for us live, and then gradually return to the earth. In burning the dead some prefer to burn the whole body to pure ash. This was the ancient method; but it is highly probable that the ashes which they obtained were a delusion in most cases. The amount of ash found in the urns, is often extremely small. The body cannot be reduced to an infinitesimal ash, as is supposed; eight to twelve pounds of matter remain from an average man when all is over. A second plan, is to drive off all volatile matter, and leave

a cinder. This disgusting plan leaves the body black and incorruptible. It can never, in any time known to us, mix with its mother earth, and yet ceases at once to resemble humanity in the slightest degree; it will not even for a long time assist us by adding its composition to the fertility of the soil. The burning of bodies never could have been general, and never can be general. Fire has only a limited use as a disinfectant. It cannot be used in the daily disinfection of the dejecta of animals, and is applied only occasionally, where the most rapid destruction is the most desirable, either because the substance has no value, or it is too disgusting to exist, or the products after burning are not offensive. There are two methods of using fire, charring or burning to ashes. The second is an act of

Oxidation.—This is effected either by rapid combustion called fire; by slow combustion, the natural action of the air; or by chemical agency, sometimes assisted by mechanical. Slow oxidation in the soil is a process which is desirable in every respect, and it would be well if we could bring all offensive matter into this condition; the ammonia is preserved, or it is in part oxidised into nitric acid and water, both the ammonia and nitric acid being food for plants. Sometimes this process is hastened by mixing up the manure with alkaline substances, raising it in heaps, and watering, by this means forming nitrates, a process performed abundantly in warm countries upon the materials of plants and animals, and imitated even in temperate regions with success. This amount of oxidation destroys a good deal of the carbonaceous substances, and leaves less for the land. It is only valuable when saltpetre is to be prepared.

One of the most thorough methods of oxidation, is by the use of the manganates or permanganates. They transfer their oxygen to organic substances with great rapidity, and completely destroy them. They are therefore complete disinfectants. They destroy the odour of putrid matter rapidly, and oxidise sulphuretted hydrogen, and phosphuretted hydrogen, as well as purely organic substances. As they do this by oxidation at a low temperature, they are the mildest form of the destructive disinfectants, and their application to putrid liquids of every kind will give most satisfactory results. The quantities treated at a time should not be great, and the amount of material used must be only to the point of stopping the smell, or at least not much more, because both pure and impure matter act on the manganates, and an enormous amount of the material may be used in destroying that which is not at all offensive. The manganates do not prevent decay from beginning again. Their use has been patented by Mr. Condy. A similar action takes place with various high oxides and other oxides which are not high. Sometimes, however, a deleterious gas is produced as a secondary result by oxidation, as when sulphuric acid in the sulphates oxidises organic matter, allowing sulphuretted hydrogen to escape. In this case it is highly probable that a true disinfection takes place, or a destruction of the putrid substance, and all offensive purely organic substances; still the amount of sulphuretted hydrogen given off, is of itself sufficiently offensive and deleterious, although not properly speaking an infectious or putrid gas, but an occasional accompaniment.

Nitric acid is another agent of destruction or oxidation, although it has qualities which might cause it to be ranked amongst those which prevent the decomposition by entering into new combinations. But properly speaking, it is not nitric acid which is the disinfectant of Carmichael Smyth, but nitric oxide, which is a powerful oxidiser, and most rapidly destroys organic matter. For very bad cases, in which gaseous fumigation is applicable, nothing can be more rapid and effective in its action than this gas. Care must be taken that there is no one present to breathe it, as it has a powerful action on the lungs, and care must be taken that metallic surfaces which are to be preserved clean, be well covered with a coating of varnish. This was used with great effect in ships and hospitals for some years, beginning with 1780, and so much good did it do, that the Parliament in 1802 voted Dr. C. Smyth a pension for it. Guyton-Morveau was vexed at this, and wrote an interesting volume concerning his mode of fumigating by acids; but in reality acids alone are insufficient, and his favourite muriatic acid has no such effect as nitrous fumes, which so readily part with their oxygen.

Chlorine is another destructive agent, and its peculiar action may be called an oxidation. When used as a gas, it has a great power of penetration, like nitrous fumes, and stops all putrefaction. It has a more actively destructive power than oxygen alone, even when its action is that of oxidation only. It decomposes compounds of ammonia into water and nitrogen, and as putrefactive matter is united with, or composed partly of nitrogen, it destroys the very germ of the evil. By the same power it destroys the most expensive part of a manure, the ammonia. It cannot therefore be used where the offensive matter is to be retained for manure. When chlorine is united with lime or soda, it may be used either as a powder in the first case, or as a liquid in either case. For direct application to the offensive substances a solution is used, or the powder. This latter acts exactly as the gaseous chlorine, but the

power of destroying ammonia is greater. As a liquid, it acts too rapidly; as a solid, the chloride of lime soon attracts moisture, and soon loses its power. Some people use the chloride of lime as a source of chlorine; they pour sulphuric acid on it, and so cause it to give out chlorine, which escapes as a gas, and acts as aforesaid. This has not been found agreeable, or indeed more than partially useful. Too much is given out at first, too little at last. It is said to have increased the lung diseases at hospitals, where it was much used in Paris. When only a minute quantity of gas is given out, as at bleach works, it certainly causes a peculiar freshness of feeling, and the appearance of the people is much in its favour, nor has it ever there been known to affect the lungs. For violent action, in cases of great impurity, it is a great disinfectant, and to be preferred to nitrous fumes, probably causing a less powerful action on the lungs. *Eau de javelle* is a chloride of potash used in Paris. Sometimes oxygen, or at least air, is used alone, to remove both colour and smell, oils having it pumped into them. Sometimes acids alone are used for disinfection. As putrid compounds contain ammonia or organic bases, they may be removed, or at least they may be retained in combination, and in this way restrained from further evaporation. This seems to be the way in which muriatic acid acts, and all other merely acid agents. This acid, so much valued at one time, is now entirely disused, as it ought to be, because it is exceedingly disagreeable to breathe, and destructive of nearly all useful substances which it touches, being at the same time a very indirect disinfectant. Acids poured on putrid matters, no doubt destroy the true putrefaction, but they cause the evolution of gases exceedingly nauseous, and of course unwholesome. This evolution does not last long, but long enough to make them useless as disinfectants when used so strong. Vinegar is the best of the purely acid disinfectants; wood vinegar the best of the vinegars, because it unites to the acidity a little kreasote. Vinegar is a very old and well established agent; it has been used in the case of plague and various pestilences from time immemorial. It is used to preserve eatables of various kinds. For fumigation no acid vapour used is pleasant except vinegar, and in cases where the impurity is not of the most violent kind, it may be used with great advantage. Even this however acts on some bright surfaces, a disadvantage attending most fumigations.

Sulphurous acid, or the fumes of burning sulphur, may be treated under this head, although in reality it does not act as a mere acid combining with a base and doing no more. It certainly unites with bases so that it has the advantage of an acid, but it also decomposes by precipitating its sulphur, as when it meets sulphuretted hydrogen. It therefore acts as an oxidiser in some cases, but it is generally believed, from its desire to obtain oxygen, that it acts by being oxidised, thus showing the peculiar characteristics of a deoxidiser. We can certainly believe that bodies may be disinfected both by oxidation and deoxidation. The solutions of sulphurous acid act as a restraint on oxidation, and preserve like vinegar. Its compounds with bases, such as its salts of soda, potash, &c., preserve also like vinegar, saltpetre, &c.; probably from their affinity for oxygen, taking what comes into the liquid before the organic matter can obtain it. But it is not probable that this rivalry exists to a great extent; the presence of the sulphurous acid in all probability puts some of the particles of oxygen in the organic matter in a state of tension or inclination to combine with it, so that the tension of the particles which are inclined to combine with the oxygen of the air is removed.

Sulphur fumes are amongst the most ancient disinfectants held sacred in early times from their wonderful efficacy, and still surpassed by none. With sulphur the shepherd purified or disinfected his flocks, and with sulphur Ulysses disinfected the suitors which he had slain in his house. No acid fumigation is less injurious generally, vinegar excepted, to the lungs or furniture, and its great efficiency marks it out as the most desirable, although much laid aside in modern times. The amount arising from burning coal must have a great effect in disinfecting the putrid air of our streets, and rendering coal-burning towns in some respects less unpleasant; this is one of the advantages which that substance brings along with it, besides, it must be confessed, greater evils. It is curious that this compound of sulphur should be one of the most efficient agents in destroying sulphuretted hydrogen, another compound of sulphur. Sulphurous acid prevents decomposition, and also preserves the valuable principle of a manure, so that it belongs partly to the class of disinfectants, and partly to antiseptics.

The peculiar actions of sulphurous acid and kreasote have been united in that called "McDougall's Disinfecting Powder." Since in towns and farms, when disinfectants are used, it is desirable not to use liquids, these two have been united into a powder, which assists also in removing moisture, as water is often a great cause of discomfort and disease in stables and cowhouses. When they are used in this manner the acids are united with lime and magnesia. When the floors of stables are *sanded* with the powder, it becomes mixed with the manure, which does not lose ammonia, and is found afterwards much more valuable for land. The cattle are also freed from a great

amount of illness, because the air of the stable is purified. When fæces of any kind cannot be at once removed by water, as by the water-closet system, the use of this is invaluable; but it is well to know that the instant removal of impurity by water is generally best for houses, however difficult the after problem may be when the river is polluted. In stables and cowhouses this is not the case, and it is then that a disinfecting powder becomes so valuable, although it is true that so many towns are unfortunately so badly supplied with water-closets that disinfectants are still much wanted for the middens.

The inventors have proposed to disinfect sewers, as well as sewage, by the same substances; not, however, in the state of a powder. They apply the acids to the sewage water in the sewers themselves, and so cause the impure water to pass disinfected through the town; by this means the towns and sewers are purified together. When the sewage water is taken out of the town it can be dealt with either by precipitation or otherwise. As it will cease to be a nuisance, covered passages for it will not require to be made.

Lime is used for precipitating sewage water, and acts as a disinfectant as far as the removal of the precipitate extends, and also by absorbing sulphuretted hydrogen, which, however, it allows again to pass off gradually. The other substances proposed for sewers have chiefly relation to the precipitation, and do not so readily come under this article. Charcoal has been mentioned; alum has been proposed, and it certainly does act as a disinfectant and precipitant. None of these substances have been tried on a great scale excepting lime. An account of the Leicester experiment by lime will come under the article SEWAGE.

Absence of air is an antiseptic of great value. The process of preserving meat, called Appert's process, is by putting it in tin vessels with water, boiling off a good deal of steam, to drive out the air, and then closing the aperture with solder. Schroeder and De Dusch prevented putrefaction for months by allowing no air to approach the meat without passing through cotton; so also veils are found to be a protection against some miasmas. *Salts*, or compounds of acids with bases, are valuable antiseptics; some of them are also disinfectants, that is, they remove the state of putrefaction after it has begun. An antiseptic prevents it, but does not necessarily remove it. Common salt is well known as a preserver of flesh; nitrate of potash, or saltpetre, is a still more powerful one. Some of these salts act in a manner not noticed when treating of the preceding substances, viz. by removing the water. Meat, treated with these salts, gives out its moisture, and a strong solution of brine is formed. Chloride of calcium prevents, to some extent, the putrefaction of wood. Alum, or the sulphate of alumina, is not a very efficient preserver; but chloride of aluminum seems to have been found more valuable. It is sometimes injected into animals by the carotid artery and jugular vein. Meat, usually keeps a fortnight: if well packed, cleaned, and washed with a solution of chloride of aluminum, it will keep three months.

But in reality the salts of the heavier metals are of more activity as disinfectants. It has been supposed that their efficiency arose from their inclination to unite with sulphur and phosphorus, and there is no doubt that this is one of their valuable properties, by which they are capable of removing a large portion of the impure smell of bodies; but they have also an inclination to combine with organic substances, and by this means they prevent them from undergoing the changes to which they are most prone. The actual relative value of solutions it is not easy to tell. Most experiments have been made on solutions not sufficiently definite in quantity. Salts of mercury have been found highly antiseptic. Such a salt is used for preserving wood; the process is known as that of Kyan's, or kyanising. A solution of corrosive sublimate, containing about 1½ per cent. of the salt, is pressed into the wood either by a forcing pump or by means of a vacuum. The albumen is the substance most apt to go into putrefaction, and when in that condition it conveys the action to the wood. It is no doubt by its action on the albumen that the mercury chiefly acts. Thin pieces of pine wood, saturated for four weeks in a solution of 1 to 25 water, with the following salts, were found, after two years, to be preserved in this order:—1. Wood alone, brown and crumbling. 2. Alum, like No. 1. 3. Sulphate of manganese, like 1. 4. Chloride of zinc, like 1. 5. Nitrate of lead, somewhat firmer. 6. Sulphate of copper, less brown, firm. 7. Corrosive sublimate, reddish yellow and still firmer. In an experiment, in which linen was buried with similar salts, the linen was quite consumed, even the specimen with corrosive sublimate. Other experiments showed salts of copper and mercury to protect best.—*Gmelin.*

Nevertheless, all these metallic salts are found true preservers under other conditions. Chloride of manganese, a substance frequently thrown away, may be used, as Gay-Lussac and Mr. Young have shown, with great advantage, and Mr. Boucherie has shown the value of the acetate of iron. Mr. Boucherie's process is very peculiar.

He feeds the tree, when living, with the acetate of iron, by pouring it into a trough dug around the root. The tree, when cut down, has its pores filled with the salt, and the albumen in the sap is prevented from decomposing. For preservation of vegetable and animal substances, see PUTREFACTION, PREVENTION OF.

The chloride of zinc of Sir William Burnett is also a valuable disinfectant, and has more power than it would seem to possess from the experiments quoted above. Wood, cords, and canvass have been preserved by it under water for many years. It has the advantage also of being so soluble as to take up less room than most other salts, although liquids generally are inconvenient as disinfectants in many places.

Nitrate of lead is a disinfectant of a similar kind; it lays hold of sulphur, and the base unites with organic compounds. All these metals are too expensive for general use, and can only be applied to the preservation of valuable materials. Even iron is much too dear to be used as a disinfectant for materials to be thrown on the fields as manure. All are apt to be very acid, a state to be avoided in a disinfectant, unless when it is applied to substances in a very dilute state, or in an active putrid state, and giving out ammonia.—R. A. S.

See also SANITARY ARRANGEMENTS.

DISTILLATION. Distillation consists in the conversion of any substance into vapour, in a vessel so arranged that the vapours are condensed again and collected in a vessel apart.

The word is derived from the Latin *dis* and *stillo*, I drop, meaning originally to drop or fall in drops, and is very applicable to the process, since the condensation generally takes place dropwise.

It is distinguished from *sublimation* by the confinement of the latter term to cases of distillation in which the product is solid, or, in fact, where a solid is vaporised and condensed without visible liquefaction.

The operation may simply consist in raising the temperature of a mixture sufficiently to evaporate the volatile ingredients; or it may involve the decomposition of the substance heated, and the condensation of the products of decomposition, when it is termed *destructive distillation*; in most cases of destructive distillation the bodies operated upon are *solid*, and the products liquid or gaseous; it is then called *dry distillation*.

In consequence of the diversity of temperatures at which various bodies pass into vapour, and also according to the scale on which the operation has to be carried out, an almost endless variety of apparatus may be employed.

Whatever be the variety of form, it consists essentially of three parts,—the *retort* or *still*, the *condenser*, and the *receiver*.

On the small scale, in the chemical laboratory, distillation is performed in the simplest way by means of the common glass retort *a*, and receiver *b*, as in *fig.* 651. The great

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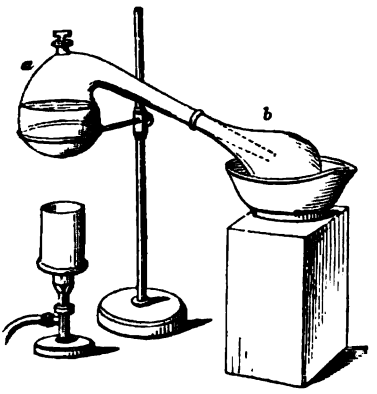

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advantages of the glass retort are that it admits of constant observation of the materials within, that it is acted upon or injured by but few substances, and may be cleaned generally with facility. Its great disadvantage is its brittleness.

The retort may be either simple, as in *fig.* 652, or tubulated, as in *fig.* 651 (*a*).

Retorts should generally be chosen sufficiently convex in all parts, the degree of curvature of one part passing gradually into that of the neighbouring portions, as is

represented in the figure; the part to be heated should, moreover, be as uniform in point of thickness as possible. The tubulated retort is more liable to crack than the plain one, on account of the necessarily greater thickness of the glass in the neighbourhood of the tubulature; nevertheless it is very convenient on account of the facility which it offers for the introduction of the materials.

In charging retorts if plain, a funnel with a long stem should be employed, to avoid soiling the neck with the liquid to be distilled: when a solid has to be introduced it is preferable to employ a tubulated retort; and if a powdered solid is to be mixed with a fluid it is preferable to introduce the fluid first.

Heat may be applied to the retort either by the argand gas flame, as in *fig.* 651, or a water, oil, or sand-bath may be employed.

In distilling various substances, *e. g.*, sulphuric acid, great inconvenience is experienced, and even danger incurred, by the phenomenon termed "bumping." This consists in the accumulation of large bubbles of vapour at the bottom of the liquid, which bursting cause a forcible expulsion of the liquid from the retort. It is prevented by the introduction of a few angular fragments of solid matter of such a nature as not to be acted upon by the liquid which is to be distilled. Nothing answers this purpose better than a piece of platinum foil cut into a fringe, or even a coil of platinum wire introduced into the cold liquid before the distillation is commenced. Even with this precaution the distillation of sulphuric acid, which it is often desirable to perform for the purpose of its purification, is not unattended with difficulty and danger.

Dr. Mohr suggests the following method*:—A glass retort of about two pounds capacity, is placed on a cylinder of sheet iron in the centre of a small iron furnace, while its neck protrudes through an opening in the side of the furnace (*fig.* 653). Ignited charcoal is placed round the cylinder, without being allowed to come in contact with the glass, and a current of hot air is thus made to play on all parts of the retort excepting the bottom, which is protected by its support. There is a valve in the flue of the furnace for regulating the draught, and three small doors in the cupola or head, for supplying fresh fuel on every side, and for observing the progress of the distillation.

Instead of the sheet iron cylinder a hessian crucible may be employed, and this, if requisite, elevated by placing it on a brick. If the vapour be very readily condensed, nothing more is necessary than to insert the extremity of the retort into a glass receiver as in *fig.* 651.

If a more efficient condensing arrangement be requisite, nothing is more convenient for use on the small scale than a Liebig's condenser, shown in *fig.* 654. It consists

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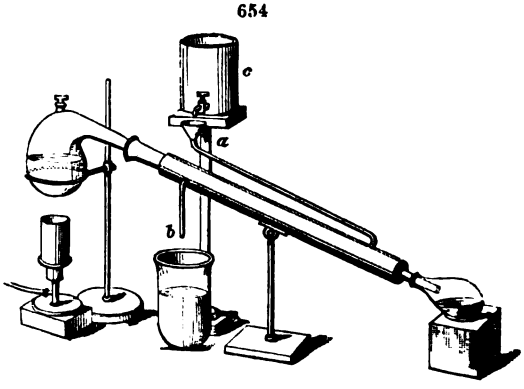

simply of a long glass tube into which the neck of the retort is fitted, and the opposite extremity of which passes into the mouth of the receiver; round this tube is fitted another either of glass or metal, and between the two a current of water is made to flow, entering at *a* and passing out at *b*. The temperature of this water may be lowered to any required degree by putting ice into the reservoir *c*, or by dissolving salts in it. (See FREEZING.)

Even on the small scale it is sometimes necessary to employ distillatory apparatus constructed of other materials besides glass.

* Mohr and Redwood's Practical Pharmacy.

Earthenware retorts are now constructed of very convenient sizes and shapes. There is one kind — which is very useful when it is required to pass a gas into the retort at the same time that the distillation is going on, as in the preparation of chloride of aluminium, &c. — which has a tube passing down into it also made of earthenware, as in *fig.* 655. The closest are of Wedgewood ware, but a common clay retort may be made impermeable to gases, by washing the surface with a solution of borax, then carefully drying and heating them.

Retorts, or flasks with bent tubes, which screw in thus (*fig.* 656), of copper, are

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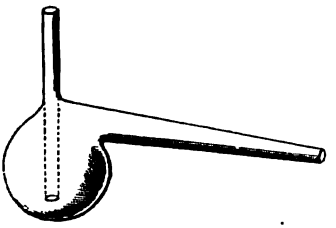

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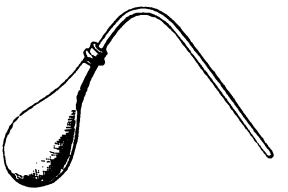

employed when it is requisite to produce high temperatures, as for the preparation of benzole from benzoic acid and baryta, or in making marsh gas from an acetate, &c.

In distilling hydrofluoric acid the whole apparatus should be constructed in lead; the receiver consisting of a U-shaped tube of lead, which is fitted with leaden stoppers so as to serve for keeping the acid when prepared; or a receiver of gutta percha may be employed with a stopper of the same material. (*Fig.* 657.)

For many purposes in the laboratory as, for instance, the preparation of oxygen by heating binoxide of manganese, — in the manufacture of potassium, &c. &c., where high temperatures are required, the iron bottles in which mercury is imported from

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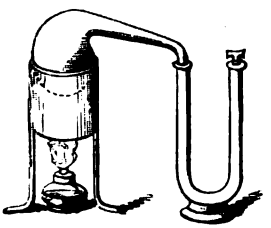

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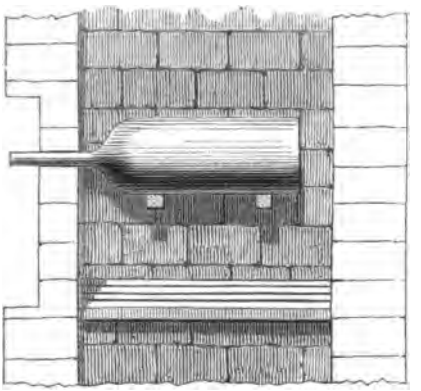

Spain may be employed, a common gun-barrel being screwed into them to act as a delivery tube or condenser. (*Fig.* 658.)

On a large scale an almost endless variety of stills have been and are still employed, which are constructed of different materials.

The common "still" consists of a retort or still proper, in which the substance is heated; and a condenser commonly called a "worm" on account of its having frequently a spiral shape. The retort or still is generally made in two parts; the *pan* or *copper*, which is the part to which heat is applied, and is commonly set in a furnace of brickwork, and the "*head*," which is generally removed after each operation, and refixed and luted upon the pan when again used. The condenser or worm is commonly placed in a tube or other vessel of water. (See *fig.* 661.)

The still may be either constructed of earthenware, or, as is very commonly the case, of copper, either plain or electro-plated with silver, according to circumstances; less frequently platinum is employed.

The still is either heated by an open fire, as in *fig.* 658, or, as is now very commonly

the case, by steam. The still-pan (*fig.* 659) is surrounded by an outer copper jacket, and steam is admitted between them from a steam boiler under any required pressure. In this way the temperature may be regulated with the greatest nicety.

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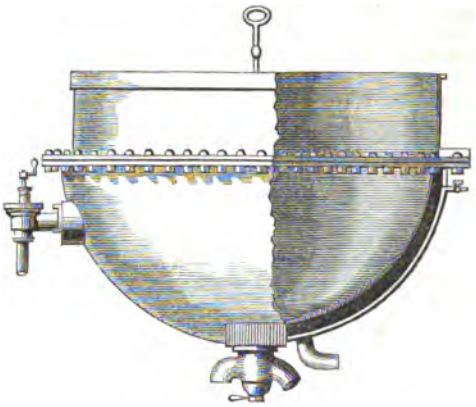

Various adaptations for heating by steam have been appropriately arranged in a very convenient form by Mr. Coffey, of Bunhill Row, Finsbury, in his so-called Esculapian Still. It is in fact a veritable *multum in parvo*, being intended to afford to the pharmaceutical chemist the means of conducting the processes of ebullition, distillation, evaporation, desiccation, &c., on the small scale, by the heat of a gas-furnace. The following cut (*fig.* 660) represents this apparatus.

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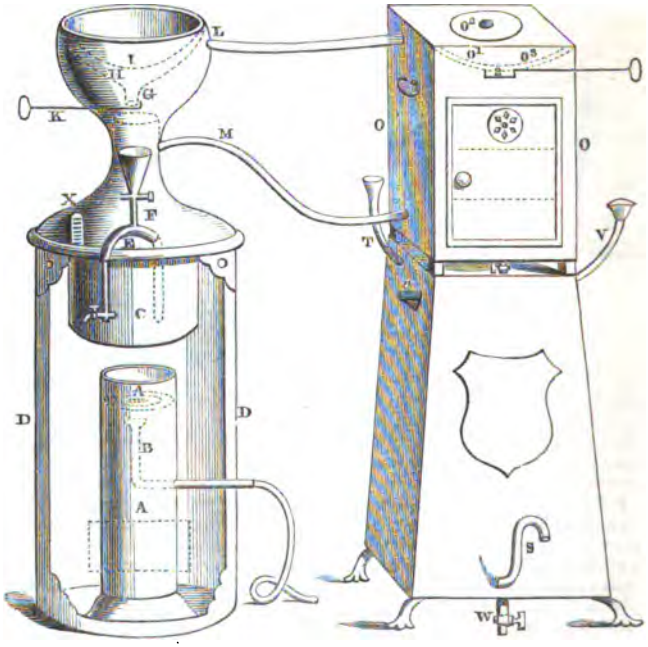

B, a burner supplied with gas by a flexible tube. C, the boiler or still. I, an evaporating pan fixed over the boiler and forming the top of the still-head. K, a

valve for shutting off the steam from I, when it passes through the tube M, otherwise it would pass through L, and communicate heat to the drying-closet o o, and from thence to the condenser T T. o is a second evaporating pan over the drying-closet. Another arrangement for distilling by steam is shown in *fig.* 661.

Sometimes also distillation is effected by passing hot steam through a worm contained *within* the still, instead of or in addition to, the application of heat from without.

The worm or condenser is frequently constructed of earthenware, and set in an earthenware vessel, these are very convenient when the operation is not to be conducted on a very large scale, and only at a moderate temperature. They are now to be obtained of all manufacturers of stone-ware articles. More commonly the worm is of copper, tin, or copper lined with silver, and in some rare cases where the liquids to be distilled act upon both copper and silver, of platinum. (*Fig.* 662.)

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A tube of the shape shown in *fig.* 663 is found more convenient than the worm, on account of its exposing a larger surface, and also because it can be placed into a

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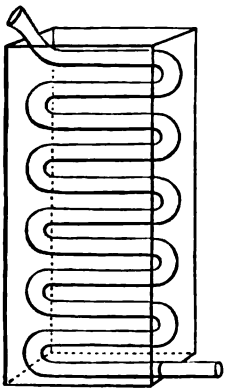

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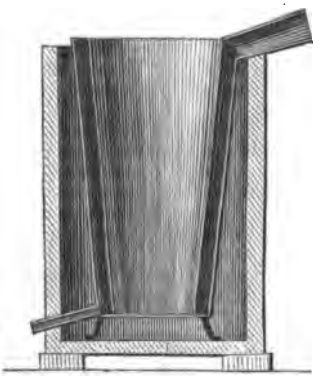

vessel of a prismatic form which occupies but little space: the water employed for condensation enters at the bottom and passes out at the top.

Gadda's condenser is represented in *fig.* 664. It consists of two conical vessels of metal, of unequal size the smaller being fixed within the other, and the space between

them closed at the bottom. These are placed in a tub filled with cold water, which comes in contact with the inner and outer surfaces of the cones, while the space between is occupied by the vapour to be condensed. This condenser is subject to the objection which applies to the common worm, that it cannot be easily and efficiently cleaned.

To obviate this, Professor Mitscherlich has proposed a very simple modification in its form, in which the inner cone is movable, so that, when taken out, the intervening space between it and the outer cone can be cleaned, and then the inner cone replaced previously to commencing an operation.

Distillation of Spirits.— In the manufacture of *ardent spirits*, the alcoholic liquor obtained by fermentation of a saccharine solution is submitted to distillation; the alcohol being more volatile than the water passes over first, but invariably a considerable proportion of water is evaporated and condensed with the alcohol. To separate this water to the required extent it is necessary either to submit the product to redistillation, or to contrive an apparatus such that the product of this first distillation is returned to the still until a spirit of the required strength is obtained.

One of the earliest and simplest contrivances for effecting the latter object is the still invented by Dorn, which is employed up to the present time in Germany (*fig.* 665). A is the still, heated by the direct action of the fire; B the head, from which *r* conveys vapour to a small refrigerator, for the purpose of testing the strength of the distillate; E is an ordinary condenser containing worm, &c. The intermediate copper vessel answers two purposes; the upper part C forming a heater for the wash, while the lower compartment D acts as a rectifier. The heater C, when filled up to the level of the

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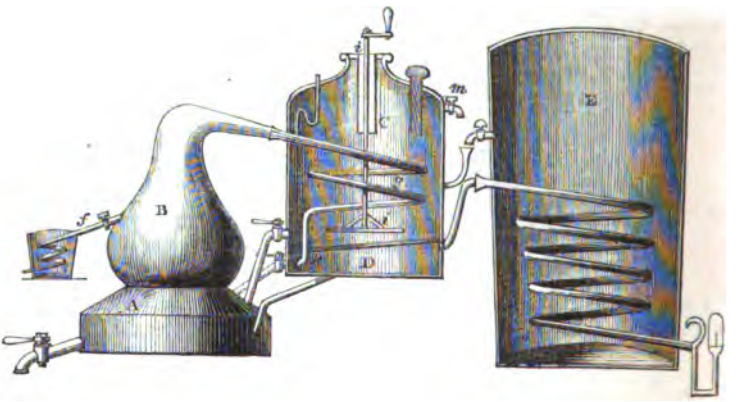


cock *m*, contains the exact measure of wash for charging the still; the contents can be constantly agitated by the rouser *i*. The still and heater being both charged, the vapour will at first be completely condensed in passing through the worm *g*, and flowing into D will close the aperture. When the contents of C become so hot that no more condensation occurs, the vapour will escape by bubbling through the liquid in D, which latter rapidly becomes heated to the boiling point, and evolves vapours richer in alcohol, which in their turn are condensed in E.

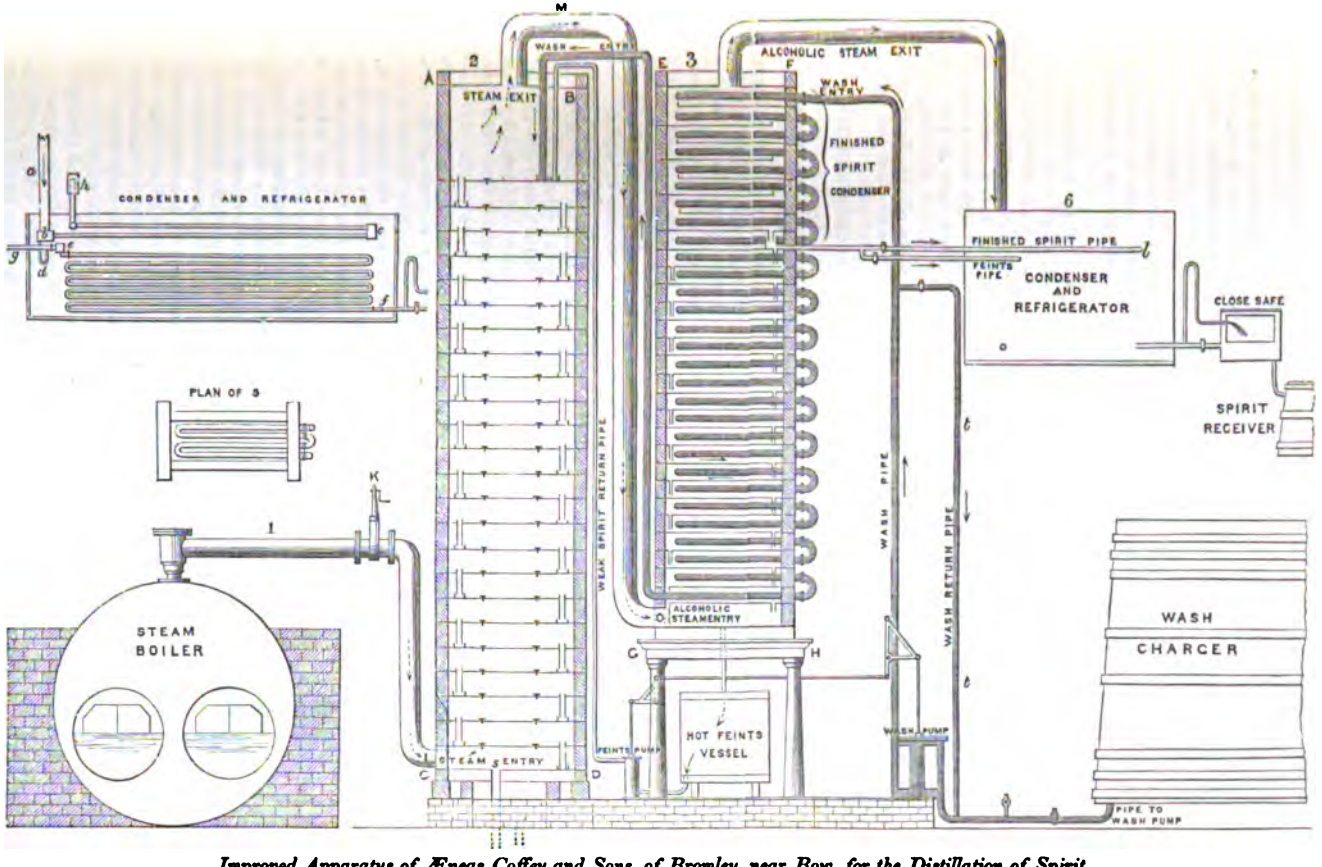
In this manner, by one operation, spirit containing about 60 per cent. of alcohol is obtained.

Of the recent improvements on Dorn's still two only need be described:—Coffey's, which has in a great measure replaced all others in this country, and Derosne's, which is extensively employed in France.

Coffey's still far surpasses any of those before described. It was patented in 1832, and has proved most valuable to the distiller, since it yields the strongest spirit that can be obtained on the large scale.

Its objects are twofold:— 1st, to economise the heat, as much as possible, by exposing the liquid to a very extended heated surface; 2nd, to cause the evaporation of the alcohol from the wash by passing a current of steam through it.

The wash is pumped from the "wash charger" into the worm tube, which passes from top to bottom of the rectifier. In circulating through this tube its temperature is raised to a certain extent. Arrived at the last convolution of the tube in the rectifier the wash passes by the tube M M in at the top of the "analyser." It falls and



Improved Apparatus of Æneas Coffey and Sons, of Bromley, near Bow, for the Distillation of Spirit.

collects upon the top shelf until this overflows, whence it falls on to the second shelf and so on to the bottom. All the while steam is passed up from the steam boiler through fine holes in the shelves, and through valves opening upwards. As the wash gradually descends in the analyser it becomes rapidly weaker, partly from condensation of the steam which is passed into it, and partly from loss of alcohol, either evaporated or expelled by the steam; till, when it arrives at the bottom, it has parted with the last traces of spirit. At the same time the vapour, as it rises through each shelf of the analyser, becomes continuously richer in alcohol, and contains less and less water in consequence of its condensation; it then passes from the top of the analyser in at the bottom of the lower compartment of the rectifier. Here it ascends in a similar way, bubbling through the descending wash, until it arrives at F, above which it merely circulates round the earlier windings of the wash pipe, the low temperature of which condenses the spirit, which, collecting on the shelf at F, flows off by the tube into the finished spirit condenser.

In order still further to economise heat, the water for supplying the boiler is made to pass through a long coil of pipe, immersed in boiling hot spent wash, by which means its temperature is raised before it enters the boiler. In fact the saving of fuel by the employment of this still is so great, that only about three-fourths of the quantity is consumed that would be requisite for distilling any given quantity of alcohol in the ordinary still; and Dr. Muspratt estimates that in this way a saving will be effected throughout the kingdom of no less than 140,000 tons of coal per annum.

Very few persons have any idea of the enormous size of some of the distilleries. One of Mr. Coffey's stills at Inverkeithing works off 2000 gallons of wash per hour, and one, more recently erected at Leith, upwards of 3000 gallons.

Derosne's still is very similar, in the principle of its action, to Coffey's, differing in fact only in the mechanical details by means of which the result is obtained.

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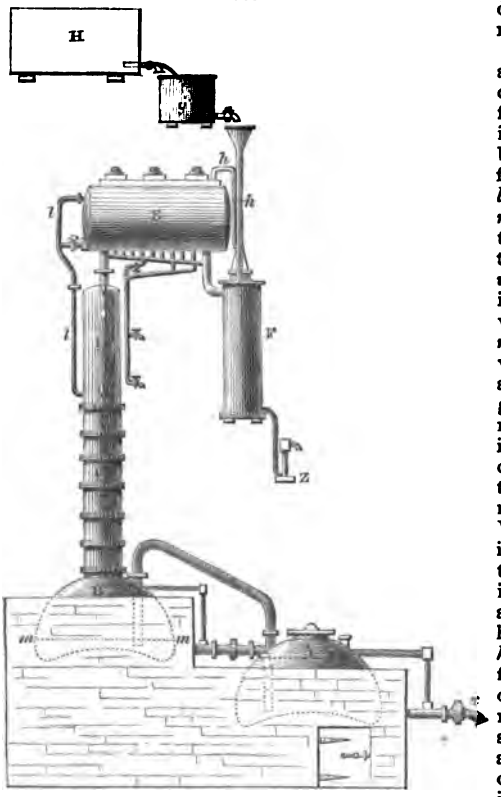

It consists of two stills, A and B, *fig.* 667. The mixture of steam and alcohol vapour from A passes into the liquid in B, which it raises to the boiling point. The vapours from B rise through the *distillatory* column C, and D (the *rectificatory* column); hence they traverse the coils of tubing in E (the *condenser* and *wine heater*), and the alcohol is finally condensed by traversing the worm in F (the *refrigerator*), whence it is delivered at Z. At the same time a steady current of the original alcoholic liquor is admitted from the reservoir H, into the exterior portion of the condenser F, by means of the tap, the flow from which is regulated by the ball cock *g*. Whilst condensing the spirit in the worm the wash has its temperature raised, especially in the upper part, and thence it ascends by the tube *h* into the heater E, by the small orifices *k k*, *fig.* 668, where it is still further heated by the current of heated alcohol which has risen into the worm from the stills, whilst at the same time assisting in the condensation of the spirit. After performing its office of condensation, and when nearly at the boiling point, the alcoholic liquor passes out by the tube *l*, and

is conducted to the top of the distillatory column c. Here it trickles down over a series of lenticular discs of metal (shown in *fig.* 668), so contrived as to retard its

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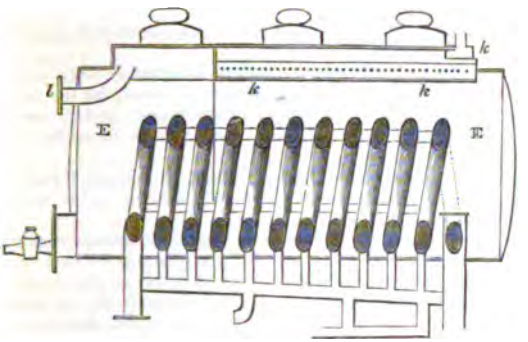

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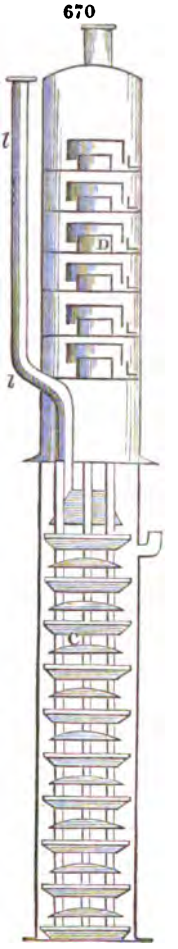

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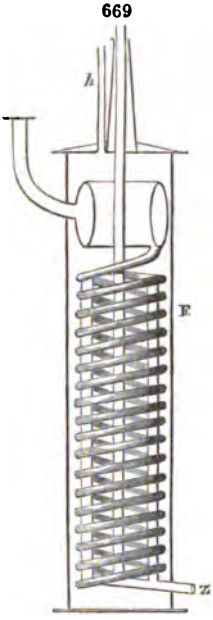

progress into the still B, and yet permit the ascent of the steam. In this distillatory column (c, *fig.* 670) it meets the steam rising from the still B. The greater part of its alcohol is expelled, which, traversing the series of condensers before described, is ultimately liquefied and collected at z; but, to complete the rectification, it descends into the still B, and, when above a certain level (*m m*), into A, which stills being heated by a furnace beneath, the final expulsion of alcohol is accomplished, and the spent liquor run off at *x*.

The details of the construction of the apparatus employed in the distillation of spirits have been here given, since this process is perhaps one of the most important of the kind; but various modifications are employed in the distillation of other liquids.

In some cases, unusually effectual condensing arrangements are required, as in the manufacture of ETHER, CHLOROFORM, BISULPHIDE OF CARBON, and BICHLORIDE OF CARBON.

In others higher temperatures are necessary, as in the distillation of sulphuric acid.

When the liquids to be distilled are acid, or otherwise corrosive, great care has to be taken especially that the worm or other condenser is of a material not acted upon by the acid. See ACETIC ACID, and SULPHURIC ACID.

The term distillation is sometimes applied to cases of the volatilisation and subsequent condensation of the metals either in their preparation or purification.

In cases like mercury, potassium, and sodium, where they are condensed in the liquid state, or visibly pass through this state before volatilisation, this term is quite appropriate; but where the fusing and vaporising points nearly coincide, as in the case of arsenic, the term sublimation would be more suitable.

Nevertheless it is difficult to draw a precise line of demarcation between the two terms; for in the cases of zinc, cadmium, &c., the metals being melted before volatilisation, and condensed likewise in the liquid state, the term is certainly correct.

For the details of construction of the distillatory apparatus we must refer to the articles on these several metals.

Distillatio per descensum is a term improperly applied to certain cases of distillation where the vapour is dense, and may be collected by descending through a tube which

has an opening in the top of the distillatory vessels, and descends through the body of the vessel in which the operation of evaporation is going on, being collected below.

This is clearly merely due to the fact of the vapour being even at a high temperature more dense than atmospheric air, and might be performed with any body forming a dense vapour, such as mercury, iodine, zinc, &c.

It has, however, practically been confined to the English process of refining zinc. See ZINC.

The two most remarkable cases in which the process of destructive distillation is carried out on a manufacturing scale, are the dry distillation of wood, for the manufacture of wood charcoal, acetic acid, and pyroxilic spirit (which see); and of coal, for the purpose of obtaining coal gas, and coke. This process will be found fully described in the article on COAL-GAS.

Distillation of Essential Oils or Essences. — The separation of volatile flavouring oils from plants, &c, by distillation with water, will be fully treated under another head. See PERFUMERY, ESSENCES.

Fractional Distillation.—A process for the separation of volatile organic substances (such as oils) is very extensively employed in our naphtha works under this name.

If we have two volatile bodies together, but differing appreciably in their boiling points, we find, on submitting them to distillation in a retort, through the tubulature of which a thermometer is fixed, so that its bulb dips into the liquid, that the temperature remains constant (or nearly so) at the point at which the more volatile constituent of the mixture boils, and the distillate consists chiefly of this more volatile ingredient; and only after nearly the whole of it has passed over, the temperature rises to the point at which the less volatile body boils. Before this point has been reached, the receiver is changed, and the second distillate collected apart. By submitting the first product to repeated redistillation, as long as its boiling point remains constant, the more volatile constituent of the mixture is ultimately obtained in a state of absolute purity. See NAPHTHA.

This method may in fact be adopted when the mixture contains several bodies; and by changing the receiver with each distinct rise of temperature, and repeating the process several times, a *fractional* separation of the constituents of the mixture may be effected.—H. M. W.

DISTILLATION, DESTRUCTIVE. Organic matters may be divided into two groups, founded on their capability of withstanding high temperatures without undergoing molecular changes. Bodies that distil unchanged form the one, and those which break up into new and simpler forms, the other. The manner in which heat acts upon organic substances differs not only with the nature of the matters operated upon, but also with the temperature employed. We shall study the subject under the following heads:—

1. *Apparatus for destructive distillation.*
2. *Destructive distillation of vegetable matters.*
3. *Destructive distillation of animal matters.*
4. *Destructive distillation of acids.*
5. *Destructive distillation of bases.*
6. *General remarks.*

1. *Apparatus for destructive distillation.*—Destructive distillation on a large scale is most conveniently performed in the cast iron retorts used in gas works. Where quantities of materials not exceeding fifteen or twenty pounds are to be operated on, for the purpose of research, a more handy apparatus can be made from one of the stout cast iron pots sold at the iron wharves. They are semi-cylindrical, and have a broad flange round the edge. The cover should be made to fit in the manner of a saucepan lid. The aperture by which the products of distillation are to be carried away should be of good size, and the exit pipe must not rise too high above the top of the pot before it turns down again. This is very essential in order to prevent the less volatile portion of the distillate from condensing and falling back. The exit tube should conduct the products to a receiver of considerable capacity, and of such a form as to enable the solid and fluid portions of the distillate to be easily got at for the purpose of examination. From the last vessel another tube should conduct the more volatile products to a good worm supplied with an ample stream of cold water. If it be intended to examine the gaseous substances yielded by the substances under examination, the exit pipe of the worm must be connected with another apparatus, the nature of which must depend on the class of bodies which are expected to come over. If the most volatile portions are expected to be basic, it will be proper to allow them to stream through one or more Woulfe's bottles half filled with dilute hydrochloric acid. Any very volatile hydrocarbons of the C^nH^n family which escape may be arrested by means of bromine water contained in another Woulfe's bottle. The pressure in the Woulfe's bottles must be prevented from becoming too great, or the leakage between

the flange of the pot and its cover will be very considerable. The luting may consist of finely sifted Stourbridge clay, worked up with a little horse dung. A few heavy weights should be placed on various parts of the lid of the pot, so as to keep it close, and render the leakage as little as possible. For the destructive distillation of small quantities of substances, I have been accustomed for a long time to employ a small still made from a glue pot, and having a copper head made to fit it. The luting for all temperatures not reaching above 700 may be a mixture of ⅔ths linseed and ⅓th almond meal, made into a mass of the consistence of putty. For the apparatus employed in the destructive distillation of wood, coal, bones, &c., on the large scale, the various articles in this work on the products obtained from those substances must be consulted.

2. *Destructive distillation of vegetable matters.*—The principal vegetable matters which are distilled on the large scale are wood and coal. We shall consider these separately.

Destructive distillation of wood.—The products obtained in the ordinary process of working are acetic acid, wood spirit or methylic alcohol, acetone, pyroxanthine, xylite, lignine, paraffine, kreosote, or phenic acid, oxyphenic acid, pittacal, several homologues of benzole, with ammonia, and methylamine. There are also several other bodies of which the true nature is imperfectly known. The greater part of the above substances are fully described in separate articles in this work. See ACETIC ACID, PARAFFINE, &c.

Peat appears to yield products almost identical with those from wood.

Destructive distillation of coal.—The number of substances yielded by the distillation of coal is astonishing. It is very remarkable that the fluid hydrocarbons produced at a low temperature are very different to those distilling when a more powerful heat is employed. The principal fluid hydrocarbons produced by the distillation and subsequent rectification of ordinary gas tar are benzole and its homologues; see HYDROCARBONS. But if the distillate is procured at as low a temperature as possible, or Boghead coal be employed, the naphtha is lighter, and the hydrocarbons which make its chief bulk belong to other series. See NAPHTHA.

3. *Destructive distillation of animal matters.*—Bones are the principal animal substances distilled on the large scale. The naphthas which come over are excessively fœtid, and are very troublesome to render clean enough for use. The products contained in bone oil will be described in the article NAPHTHA. Horn and wool have recently been examined with reference to the basic products yielded on distilling them with potash. Horn under these circumstances yields ammonia and amylamine. Wool I find to afford ammonia, pyrrol, butylamine, and amylamine. My experiments on feathers, made some years ago, although not carried so far as those on wool, appear to indicate a very similar decomposition.

The products yielded by animal matters, when distilled *per se*, are very different to those obtained when a powerful alkali is added previous to the application of heat. If feathers or wool be distilled alone, a disgustingly fœtid gas is evolved containing a large quantity of sulphur. Part of the sulphur is in the state of sulphide of carbon. But if an alkali be added previous to the distillation, the sulphur is retained, and the odour evolved, although powerful, is by no means offensive. During the whole period of the distillation of ordinary organic matters containing nitrogen, pyrrol is given off, and may be recognised by the reaction afforded with a slip of deal wood dipped in hydrochloric acid. An interesting experiment, showing the formation of pyrrol from animal matters, may at any time be made with a lock of hair, or the feather of a quill. For this purpose the nitrogenous animal matter is to be placed at the bottom of a test tube, and a little filtering paper is to be placed half way up the tube, to prevent the water formed during the experiment from returning and fracturing the glass. The end of the tube is now to be cautiously heated with a spirit lamp, and, as soon as a dark yellowish smoke is copiously evolved, a slip of deal previously moistened with concentrated hydrochloric acid is to be exposed to the vapour. In a few seconds the wood will acquire a deep crimson colour. The fact of the presence of sulphur in wool, hair, or other albuminous compounds of that description, may be made very evident to an audience by the following experiment. Dissolve the animal matter in very concentrated solution of potash in a silver or platinum basin, with the aid of heat. Evaporate to dryness, and raise the heat at the end to fuse the potash and destroy most of the organic matters. When cold, dissolve in water, and filter into a flask half full of distilled water. To the clear liquid add a little of Dr. Playfair's nitroprusside of sodium; a magnificent purple tint will be immediately produced, indicative of the presence of sulphur. A very small quantity of hair or flannel will suffice to yield the reaction.

The above remarks on destructive distillation apply principally to highly complex bodies, the molecular constitution of which is either doubtful, as in the case of albuminous substances, or totally unknown, as with coals and shales. The destructive

distillation of organic substances of comparatively simple constitution, such as acids and alkalies, sometimes yields products, the relation of which to the parent substance can be clearly made out. This holds more especially in the case of organic acids; the bases too often yield such complex results, that the decomposition cannot be expressed by an equation giving an account of all the products. We shall study a few cases separately.

4. *Destructive distillation of acids.*—The destructive distillation of acids takes place in a totally different manner, according as we have a base present or the operation is carried on without any addition. Many if distilled *per se* undergo a very simple reaction, consisting in the elimination of carbonic acid, and the formation of a *pyroacid.* But if an excess of base be present, the decomposition often results in the formation of a ketone (see ACETONE). We shall offer a few examples of these decompositions. Gallic acid, heated to about 419° Fahr., is decomposed into pyrogallic and carbonic acids, thus:—

$$\underbrace{C^{14}H^{6}O^{10}}_{\text{Gallic acid.}} = \underbrace{C^{12}H^{6}O^{6}}_{\text{Pyrogallic acid.}} + 2CO^{2}$$

There are cases in which the action of heat upon organic acids results in the formation of two substances, not produced simultaneously, but in two epochs or stages. In reactions like this, the first effect is the removal of two equivalents of carbonic acid, and by submitting the resulting acid to heat again, two more are separated. Under these circumstances, it is the second which is generally called the pyroacid. As an example we will take meconic acid which breaks up in the manner seen in the annexed equations.

$$\underbrace{C^{14}H^{4}O^{14}}_{\text{Meconic acid.}} = \underbrace{C^{12}H^{4}O^{10}}_{\text{Comenic acid.}} + 2CO^{2} \qquad \underbrace{C^{12}H^{4}O^{10}}_{\text{Comenic acid.}} = \underbrace{C^{10}H^{4}O^{8}}_{\text{Pyromeconic acid.}} + 2CO^{2}$$

It will be seen that the hydrogen remains unaffected. Perhaps the name pyrocomenic acid would be preferable to pyromeconic acid, inasmuch as it is derived from comenic acid in the same manner as pyrogallic from gallic acid.

But pyroacids are not always derived from the parent acid by the mere elimination of carbonic acid; thus mucic acid, in passing into pyromucic acid, loses two equivalents of carbonic acid, and six equivalents of water, thus:—

$$\underbrace{C^{12}H^{10}O^{16}}_{\text{Mucic acid.}} = \underbrace{C^{10}H^{4}O^{8}}_{\text{Pyromucic acid.}} + 2CO^{2} + 6HO$$

It does not invariably happen that the destructive distillation of acids *per se* results in the formation of a pyroacid, the disruption is sometimes more profound, the products being numerous and somewhat complex. Let us take as an illustration a case where all the results can be reduced to an equation. Oxalic acid, when heated in a retort without addition, yields water, oxide of carbon, carbonic and formic acids, in accordance with the annexed equation:—

$$\underbrace{4(C^{2}O^{3},HO)}_{\text{Oxalic acid.}} = 4CO^{2} + 2CO + 2HO + \underbrace{C^{2}HO^{3},HO}_{\text{Formic acid.}}$$

The admixture of sand, pulverised pumice stone, or any other inert substance in a state of fine division, often remarkably assists in rendering the decomposition more easy and definite. Thus, if pure sand be mixed with oxalic acid, the quantity of formic acid is so increased, that the process is sometimes employed in the laboratory as a means of affording a pure and tolerably strong acid.

We have said that the destructive distillation of acids proceeds in a very different manner according as we operate upon the acid itself, or a salt of the acid. The distillation of the pure salt yields different products to those which are obtained when the salt or dry acid is mixed with a large excess of a dry base (such as quicklime), before the application of heat. If, in the former mode of proceeding, two atoms of the acid are decomposed, yielding a body containing (for four volumes of vapour, see FORMULÆ) the elements of two atoms of carbonic acid and two of water less than the parent acid, such body is called a ketone. Thus when two atoms of acetate of lime are distilled, the products are one atom of acetone, and two of carbonic acid. Of course the carbonic acid combines with the lime, thus:—

$$\underbrace{2(C^{4}H^{3}CaO^{4})}_{\text{Acetate of lime.}} = \underbrace{C^{6}H^{6}O^{2}}_{\text{Acetone.}} + 2(CaO,CO^{2}).$$

If, however, the salt is not of a very low atomic weight, and the quantities operated on are at all considerable, secondary products are formed, as in the dry distillation of

butyrate of lime, when, if the substance is not in very small quantity, carbon is deposited, and a certain quantity of butyral ($C^8H^8O^2$) is formed, and probably other substances.

As an illustration of the decomposition undergone when acids are distilled with a great excess of dry base, we shall select that of benzoic acid, which under the circumstances alluded to yields benzole and carbonate of the base.

$$\underbrace{C^{14}H^6O^4}_{\text{Benzoic acid.}} = \underbrace{C^{12}H^6}_{\text{Benzole.}} + 2\,(CO^2)$$

5. *Destructive distillation of bases.* — It has been found that the organic bases undergo a much simpler and more direct decomposition when subjected to destructive distillation in presence of alkalies than when they are exposed to heat without admixture. There are two bodies almost invariably found among the resulting products, namely ammonia and pyrrol. In this respect, therefore, the organic alkalies behave like other nitrogenised animal and vegetable products. The decomposition is almost always rather complex, and it is very rare that the products are sufficiently definite to be arranged in the form of an equation. The most common substances found, are the alcohol bases, and these are almost invariably of low atomic weight. One great difficulty connected with researches on this subject, is owing to the fact of its being seldom that the products are in sufficient quantity to enable a thorough knowledge of the molecular constitution to be arrived at. Unfortunately this information is much wanted in consequence of the numerous cases of isomerism to be met with among the alcohol bases. See FORMULÆ, CHEMICAL. Thus it is difficult, when working on very small quantities, to distinguish between bimethylamine and ethylamine, both of which have the formula C^4H^7N.

It is remarkable that there is a great similarity between the products of the destructive distillation of some of the most unlike nitrogenous substances. This is conspicuously seen in the case of bones, or rather the gelatinous tissues of bones, shale and coal naphthas, and cinchonine. An inspection of the following table, compiled from a paper (by the writer of this article), "On some of the Basic Constituents of Coal Naphtha," will render this evident.

Gelatinous Tissues.	Shale Naphtha.	Coal Naphtha.	Cinchonine.
Pyrrol.	Pyrrol.	Pyrrol.	Pyrrol.
Pyridine.	Pyridine.	Pyridine.	Pyridine.
Picoline.	Picoline.	Picoline.	Picoline.
Lutidine.	Lutidine.	Lutidine.	Lutidine.
Collidine.	Collidine.	Collidine.	Collidine.
- -	Parvoline.		
- -	- -	Chinoline.	Chinoline.
- -	- -	Lepidine.	Lepidine.
- -	- -	Cryptidine.	
Aniline.	- -	Aniline.	

It is very possible that some of the above bases, having the same formulæ, but derived from different sources, will, in course of time, prove to be merely isomeric, and not absolutely identical. The author of this article has quite recently found that the chinoline of coal tar is certainly not identical with that from cinchonine. The base from the latter source yields a magnificent and fast blue dye upon silk, when treated by a process which gives no reaction if the coal base be substituted. It is unfortunate that the reaction is with the latter instead of the former, as it would have added one more to the list of gorgeous dyeing materials yielded by coal tar.

6. *General Remarks.*—The tendency of numerous researches, made during the last few years, has been to show that there is no organic substance, capable of resisting high temperatures, which may not be found to exist among products of destructive distillation. By varying the nature of the substance to be distilled, and also the circumstances under which the operation is conducted, we can obtain an almost infinite variety of products. Acids, bases, and neutral substances, solid, liquid, and fluid hydrocarbons, organic positive, negative, and derived radicals, organo-metallic bodies, — all may be produced by the action of high temperatures on more or less complicated bodies. Much has already been done, but the facts at present accumulated relate merely to the superficial and more salient substances. On penetrating further below the surface far more valuable and interesting facts will come to light. — C. G. W.

DIVIDIVI, or *Libi Davi*, is the pod of a leguminous shrub, which is an indigenous production of Jamaica, and some parts of South America. Mr. Rootsey obtained a mean produce of 6·625 grs. of leather from 60 grs. of dividivi, while the same quantity of the best Aleppo galls yielded only a mean produce of 4·625. It appears too from Sir Humphry Davy's estimate, that 60 grs. of dividivi contain 3·0475 grs. or 5·079 per cent. of tannin, and 60 grs. of galls, 2·12704 grains, or 3·450 per cent.

Sixty grs. of oak bark yielded only 1·75 grains of leather; whence it follows that it contains but 0·805 of a grain of tannin to the drachm, or not more than 1·34166.

It has been tried as a dye instead of galls or sumach, but its use for this purpose is almost entirely abandoned. See LEATHER.

Dividivi *imported* in 1857 : —

	Tons.		£.
Curaçoa - -	229	computed real value,	2,416
New Granada -	2,517	„ „	26,554
Venezuela - -	372	„ „	3,925
Other parts - -	35	„ „	369
	3,153		£33,264

DIVING BELL. As it is frequently desirable to raise objects from the bottom of the sea or rivers, and to lay the foundation of piers and similar structures, some contrivance was desired to enable man to descend below the water, and to sustain himself while there. The first method adopted was the very simple one of letting down a heavily weighted bell vertically into the water. As the bell descended, the air got overpressed, and the water rose in the bell, but never to the top, and within that space the man was sustained for some time. The air, however, was vitiated by the processes of respiration, and the man had to be drawn up. It is curious to find that as early as 1693 a very complete system of diving without a bell was devised, as the following quotation will show.

A.D. 1693. "William and Mary, by the Grace, &c. &c. Whereas John Stapleton, gentleman, hath by his great study and expence invented a new and extraordinary engine of copper, iron, or other mettal, with glasses for light joints, and so contrived as to permit a person enclosed to move and walk freely with under water, and yet so closely covered over with leather as sufficiently to defend him from all the jumpes of it. Also invented a way to force air into any depth of water, whereby the person in the aforesaid engine may be supplied with a continual current of fresh aire, which not only serves him for respiracõn, *but may alsoe be useful for continuing a lamp burning, which he may carry about with him in his hand.* * * * Likewise a way to make the same again serviceable for respiracõn, and by continually repeating the operacõn, a man may remain a long time under water, in either of the said engines, without any other air than the sayd engines do contayne, whereby he shall be preserved from suffocation if any extraordinary accident should interrupt the current of fresh air afore mencõned."—*Letters Patent. Rolls Chapel. Edited by Bennet Woodcroft.*

The defects were many in this apparatus, and Dr. Halley invented a bell, the object of which was to remedy them.

Dr. Halley's bell was of wood coated with lead, and having strong glass windows above, to allow the passage of light to the diver. In order to supply air, a barrel was taken with an open hole in the bottom, and a weighted hose hanging by, and fitting into a hole at the top. From this barrel the air of the bell was supplied as frequently as it became vitiated, the barrels of air being sent down from above. Spalding improved upon Halley's bell, and again Friewald made some improvements on Spalding's, but in principle these bells were all alike. The modern bells are usually large and strong iron bells, with windows in the upper part. By means of an air pump, placed on the surface, air is sent down to the divers in the bell, and the vitiated air is as regularly removed from the bell by other tubes through which it escapes. These diving bells are lowered by means of cranes, and are moved about in the water by those above, signals being given by the men below. The difficulty of moving this machine, renders it still inconvenient, and recent attempts have been made to obviate this, by the construction of a diving bell upon principles entirely different. This new diving bell, to which the name of THE NAUTILUS has been applied, has proved so useful in the construction of some parts of the Victoria Docks, and some works on the Seine, that a full description of it is appended.

The nautilus machine is entirely independent of suspension; its movements are entirely dependent on the will of those within it, and without reference to those who may be stationed without; it possesses the power of lifting large weights, *per se*, and at the same time is perfectly safe, by common care in its operations. This latter is the greatest desideratum of all. These advantages must strike all as combining those requisites of success which have been always wanting in the present known means for constructing works under water.

The form of the machine is not arbitrary, but depends entirely on the nature of the work to be performed, adapting itself to the various circumstances attending any given position. By reference to the annexed figures it will be perceived that when at rest, being entirely enclosed, its displacement of water being greater than its own weight, it must float to the surface (see *fig.* 671). Entering through a man-hole at the top (which is closed either from the inside or outside), you descend into the interior of the

machine, portions of which are walled off on either side, forming chambers; these chambers are connected at or near the bottom of a pipe *a a*, which opens by a

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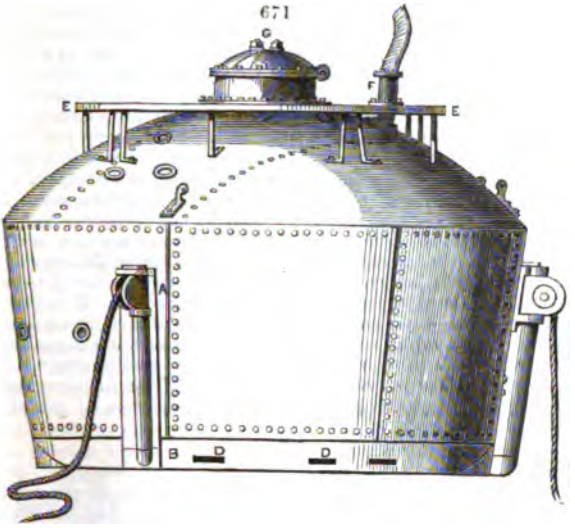

cock *b*, outwards to the external surrounding water. An opening in the bottom of the machine of variable dimensions is closed by a door or doors susceptible of being opened or closed at pleasure. The chambers w w, are likewise connected at top by

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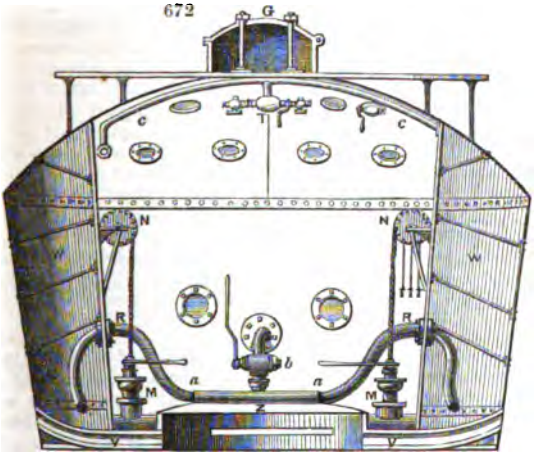

a smaller pipe *c c*, which opens through the top of the machine, and to which opening is affixed a flexible pipe, with coils of wire spirally enclosed. Branches on this latter pipe T, allow also communication with the larger or working chamber.

At the surface of the water placed on a float or vessel for the purpose, is a receiver of variable dimensions, to which is attached at one end a hollow drum or reel, to the barrel of which is affixed the other end of the flexible pipe *a*, leading to the top of the nautilus. At the other end of, and in connection with the receiver, is a powerful air-condensing pump. This combination represents the nautilus as adapted to engineering work.

As to the *modus operandi*: — The operator with his assistants enters the machine through the top, which is then closed. To descend, the water-cock *b* is opened, and the external water flows into the chambers w w; at the same time a cock, on a pipe

opening from the chambers outwards, is opened, in order that, the air escaping, an uninterrupted flow of water may take place into the chambers. The weight of water entering the chambers causes a destruction of the buoyancy of the machine, and the nautilus gradually sinks. As soon as it is fairly under water, in order that the descent may be quiet and without shock, the water-cock *b*, is closed. The receiver at the surface being previously charged by the air pump to a density somewhat greater than that of the water at the depth proposed to attain, one of the branch-cocks on the pipe *c c*, connecting the chambers at top, is opened, and the air rushes into the working chamber, gradually condensing until a density equal to the density of the water without is attained; this is indicated by proper air and water gauges. These gauges marking equal points, showing the equilibrium of forces without and within, the cover to the bottom *z* is removed or raised, and communication is made with the under water surface, on which the nautilus is resting. In order to move about in localities where tides or currents do not affect operations, it is only necessary for the workman to step out of the bottom of the nautilus, and placing the hands against its sides, the operator may move it (by pushing) in any direction.

Where currents or tides, however, have sway, it becomes necessary to depend upon fixed points from which movements may be made in any direction. This is accomplished by placing, in the bottom of the nautilus, stuffing boxes of peculiar construction (M M, *fig.* 672), through which cables may pass over pulleys to the external sides, thence up through tubes (to prevent their being worn), to and over oscillating or swinging pulleys, placed in the plane of the centre of gravity of the nautilus, and thence to the points of affixment respectively (*fig.* 673). The object to be gained by having

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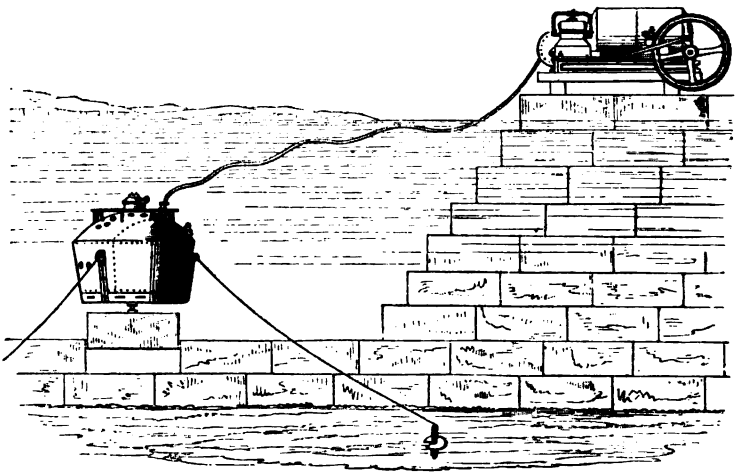

the swinging pulleys in the plane of the centre of gravity of the mass, is to hold the machine steady and to prevent oscillation. Within the machine, and directly over the above stuffing boxes, are windlasses for winding in the cables. By working these windlasses movement may be effected, and of course the number of these cables will depend on the variable character of the situation to be occupied. Having thus secured the means of descending, communicating with the bottom, and of movement, the next point is to ascend. Weight of water has caused a destruction of buoyancy at first, and consequent sinking; if then any portion of this water is removed, an upward effort will at once be exerted exactly proportionate to the weight of water thrown off. The air in the receiver at the surface being constantly maintained at a higher density than that of the water below, if we open the water cock on the top pipe, *c, c*, throwing the condensed air from the receiver above directly on to the surface of the water in the chambers, movement and consequent expulsion of the water must take place, and an upward movement of the machine itself, which will rise to the surface.

It is evident that if, previously to the expulsion of the water, the nautilus be affixed to any object below, the power exerted on that object will be exactly proportionate to the weight of water expelled, and the power will continue increasing until, there

being no farther weight to be thrown off, the maximum effect is produced. To apply this power to lifting masses of stone or rock, proper arrangements are affixed to the centre of the opening in the bottom, by which connection can be made with the weight, admitting, at the same time, the swinging around of the object suspended, so that it may be placed in any required position. In the construction of permanent work, or the movement of objects whose weight is known, or can be estimated, a water, or, so called, lifting tube is placed on the side of the water chamber, which indicates the lifting power exercised by the nautilus at any moment. The advantage of this gauge will be recognised, inasmuch as without it the closest attention of the operator, working very cautiously, would be necessary to determine when the weight was overcome; by its aid, however, the operator boldly throws open all the valves necessary to develope the power of the nautilus, watching only the gauge. The water, having reached the proper level indicating the required lifting power, he knows the weight must be overcome, or so nearly so that the valve or cocks may be at once closed, in order that the movement may take place horizontally. A moment's reflection will show that, if there were not an index of this character, carelessness or inattention on the part of the operator, by leaving the cocks open too long, might develope a power greater than required, and the nautilus would start suddenly upward. The expansive power of air, acting upon the incompressible fluid, water, through the opening in the bottom, gives a momentum which, by successive developments of expansion in the working chamber, is constantly increasing in velocity, until, in any considerable depth of water, the result would be undoubtedly of a very serious character. Take, for exemplification, the nautilus in thirty-three feet of water, and bottom covers removed, and an equilibrium, at fifteen pounds to the inch, existing between the air and the water at the level of the bottom of the machine. Upward movement is communicated the instant the machine rises in the slightest degree, the existing equilibrium is destroyed, and the highly elastic qualities of air assume preponderance, exerting, from the rigid surface of the water below, an impulsive effort upward in the direction of least resistance. At each successive moment of upward movement the impelling power increases, owing to the increasing disparity between the pressure of air within struggling for escape. The machine, thus situated, becomes a marine rocket (in reality), in which the propelling power is exhausted only when the surface is reached, and a new equilibrium is obtained. It will readily be seen that, were this difficulty not overcome, it would be impossible to govern the nautilus; for, rising with great velocity to the surface, the machine is carried above its ordinary flotation, or water line, a little more air escaping owing to the diminished resistance as that level is passed; the recoil, or surging downwards, causes a condensation of the air remaining in the chamber; a portion of the space previously occupied by air is assumed by water; the buoyant power becomes less, the machine settles slightly more by condensation of the air, a larger space is occupied by water, and the nautilus redescends to the bottom with a constantly accelerating movement, seriously inconveniencing the operator by filling more or less with water, according to depth. For many months the difficulties just enumerated baffled all attempts at control. A weight attached could be lifted, but the instant it was entirely suspended, — before the valves could be closed, — upward movement was communicated beyond control. This difficulty so fatal has been overcome by an arrangement at the bottom of the nautilus, with channels which radiate from the opening in an inclined direction, debouching at the sides of the machine. The moment then that the air, by its expansion from diminished resistance, or by the introduction from above of a greater volume than can be sustained by the water below, reaches, in its downward passage, the level of these chambers, following the direction of least resistance, it passes through these channels and escapes into the surrounding water, without of course affecting the movement of the machine in the least.

The pump for supplying air to the diving bell or other suitable vessel is represented at *figs.* 674 and 675, and is constructed as follows: — D is a cylinder, opening at the upper part into a chamber or chambers F F, separated by a partition E. On the side of each of these chambers there is a valve H H, opening inwards, and at the upper part of the same are two valves I I, opening outwards into the valve chamber G. Outside the opening for each of the valves H, H, there is a cup, into which the end of the water supply pipe M passes; by this means a small stream of water is supplied to the cup, and is drawn from it into the chamber F to supply the waste in the operation of pumping. The valve chamber G is covered with a jacket *k*, having a space between it and the valve chamber that is filled with water from the water pipe M, which affords a stream of cold water to carry off the heat from the condensed air which is forced into the chamber. The water thus supplied circulates through the tubes in the chamber and round them in the jacket, and thus cools the air in these

tubes; it is then conveyed so as to be usefully employed in a steam boiler, or is allowed to run off. The air and a small quantity of water is forced up from the

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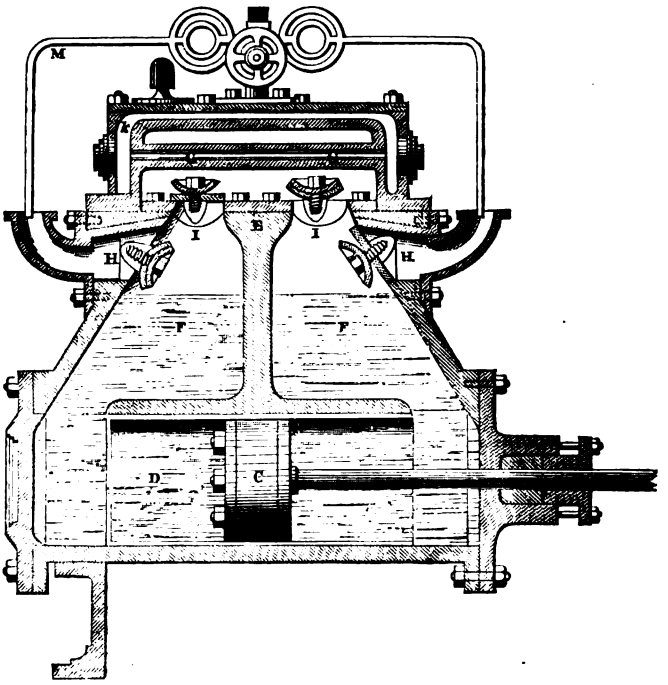

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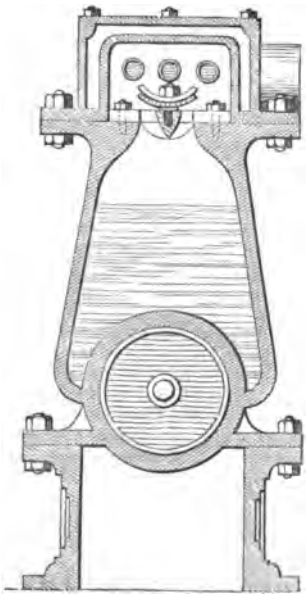

cylinder D by the stroke of the piston C into the chamber F, which is thereby filled with water, and thus the air is expelled therefrom, a small quantity of the water passing with it and covering the valves, by which means they are kept tight and wet. The air and water thus discharged, after passing around the small tubes in the valve chamber and being cooled, are forced outward and conveyed to the condenser. On the return stroke of the piston, the other chamber F is filled, and air and water expelled from it in like manner through its valve into the valve chamber. There is always a sufficient quantity of water in the cylinder D and chamber F to fill the latter when the water is all expelled from the cylinder, by the piston C having been driven to one end of it, and when the piston returns to the opposite end of the cylinder the water flows in behind it, and draws in its equivalent in bulk of air and water through the valve H. On its return, this is forced out through the valve *k* into the chamber I, as mentioned above. The water being non-elastic, if the parts are kept cool enough to avoid raising steam, this process may be continued for any length of time. A transverse section of this apparatus is shown in *fig.* 675.

Figs. 676 and 677 represent the speaking tube and alarm bell above referred to. The construction of this mechanism is as follows: — There is a hollow casting, one portion of which is trian-

gular in form, from one end of which a short tube *a* projects. This tube *a* has a screw cut on it, and a projecting flange at its junction with the triangle. This is screwed into the top of the diving vessel or armour from the inside, and projects through it to allow the coupling of a flexible or other hose to be attached to it. At the opposite angle, and in a line with *a*, there is a tubular projection *b*, provided with a screw to receive a cap *f*, to which is to be attached a piece of hose. Within the tube *f*, and at its junction with *b*, is placed a thin diaphragm of metal or other suitable material *c*, for which purpose, however, a thin silver plate that just fits the bore of the cap *f* is preferred. This diaphragm closes all communication between the diving vessel and the external air. By this means it is easy to converse through any required length of tubing. It may be desirable to fit a stop-cock into the tubular projection *b*, as a precautionary means of preventing the escape of air in the event of a rupture of the diaphragm. The upper part of the triangular enlargement of the speaking tube is tapped for a stuffing box at *g*, within which there is an axis *h*, which runs from side to side of the said enlargement, and through the stuffing box at one side. On this axis *h* is fixed a lever *i* within the said enlargement, which lever communicates with the surface of the water by means of a wire fixed at its reversed end, and running through the whole length of pipe. On the outer extremity of the axis *h* is affixed a hammer, which strikes on a bell *k* connected to the tube, as shown in the drawing. By this means the attention of the operator below may be drawn to the speaking tube when it is required to converse with him from the surface of the water, and the men whose duty it is to attend to the operator below can, by placing their ear at the end of the tube, hear the bell struck below as a signal for communication with them at the surface.

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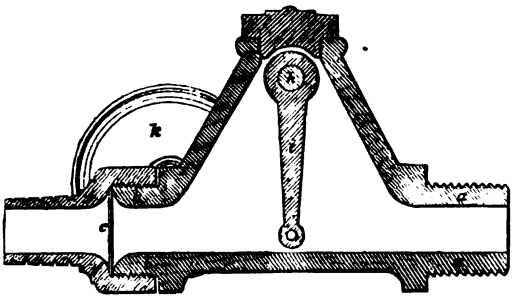

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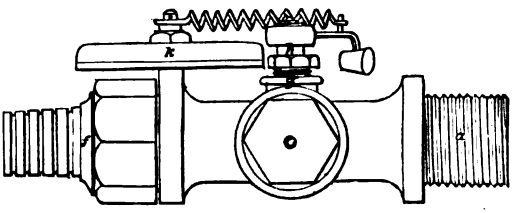

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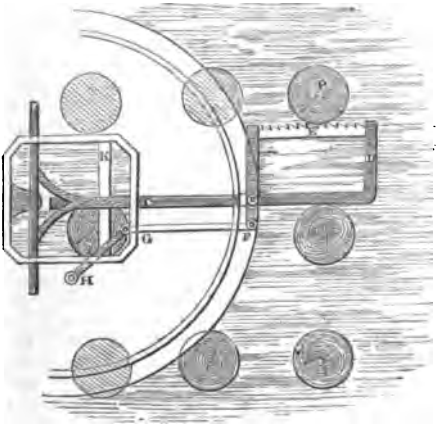

The only parts of the apparatus not yet described are the saw for cutting the tops of piles to an uniform level, the pump which enables the divers themselves to rise to the surface in the event of the flexible hose being detached or injured, and the contrivance for screwing an eye bolt into the side of the sunken vessels.

The arrangement of the saw-frame and connections are shown in *fig.* 678. Only as much of the bottom of the Nautilus is shown as will render the position of the saw understood. F is a pile which is required to be cut down to the same level as the others, E is the blade of the saw, D the framing by which it is stretched, C, D, the handle which rests on the cross bar K; to which is attached the upright part of the handle which is laid hold of by the workman inside when working the saw. H, G, F,

a bent lever with two friction rollers at F which guides the saw forwards while making the cut.

The pump for ascending in case of accident to the air hose is not shown in the drawing. It is a simple force pump placed in the working chamber, by which the ballast water in W W, *fig.* 672, can be pumped out so as to lighten the apparatus sufficiently to allow of its ascent.

The apparatus for fixing the eye bolts is shown in *fig.* 679. The operation of this apparatus is as follows: — It will be observed the chamber D opens outwards to the water, so that when the sliding partition or valve *y* is forced down by the lever *g*, the communication of the water with the chamber C is cut off. The lid *z* being removed, a bolt *i* (or other operating tool or instrument) is placed within the chamber C; the rod *k* is forced through the stuffing box *l* until the recessed end of the rod contains the end of the bolt; the small rod *j* is then screwed through the stuffing box *n*, until the screw on the end of this rod has become affixed to the end of the bolt contained within the recess at *p*. The lid *z* of the chest is then fastened on, and the partition or valve *y* raised, the stuffing box M preventing the escape of air. Communication is thus opened between the chambers A and D, the latter being open outwards. The rod *i* is now pushed outwards by pressing on the handle *k* through the stuffing box *l*, until the vessel or object to be operated upon is reached, when the operation is per-

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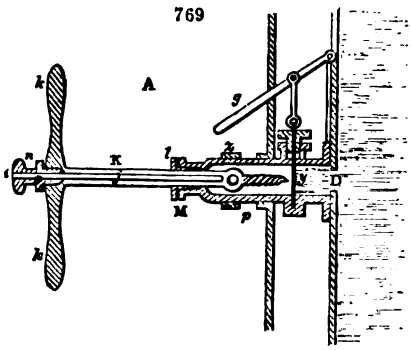


formed as required. It will be observed that the stuffing box prevents the escape of air out of the bell or the admission of water into it, the stuffing box *n* having the same tendency. After the operation with the tool or instrument is complete, the rod *k* is disconnected by unscrewing the rod *j*, and is drawn into the chamber A by means of the handle *k*; the partition or valve *y* is again lowered, and the operations above described are repeated. It will hence be obvious that a number of eye bolts might in this manner be successfully inserted in the side of a sunken vessel from the diving bell, so that by hooking on the "camels" the strain would be so distributed as to prevent injury by the process of lifting the said vessel.

DOCIMACY. From the Greek Δοκιμαζω, I prove (*Docimasie*, Fr.; *Probierkunst*, Germ.), is the art by which the nature and proportions of an ore are determined. The art of assaying minerals, the separation of the metal. This analytical examination was originally conducted in the dry way, the metal being extracted from its mineralisers, by means of heat and certain fluxes. But this method was eventually found to be insufficient and even fallacious, especially when volatile metals were in question, or when the fluxes could absorb them. The latter circumstance became a very serious evil, whenever the object was to appreciate an ore that was to be worked at great expense. Bergmann first demonstrated, in an elaborate dissertation, that the humid analysis was much to be preferred; and since his time the dry way has been devoted chiefly to the direction of metallurgic operations, or, at least, it has been employed merely in concert with the humid, in trials upon the small scale.

After discovering an ore of some valuable metal, it is essential to ascertain if its quantity and state of combination will justify an adventurer in working the mine, and smelting its products. The metal is rarely found in a condition approaching to purity; it is often disseminated in a *gangue* far more bulky than itself; and more frequently still it is combined with simple non-metallic substances, such as sulphur, carbon, chlorine, oxygen, and acids, more or less difficult to get rid of. In these compound states its distinctive characters are so altered, that it is not an easy task either to recognise its nature, or to decide if it can be smelted with advantage. The assayer,

without neglecting any of the external characters of the ore, seeks to penetrate, so to speak, into its interior; he triturates it to an impalpable powder, and then subjects it to the decomposing action of powerful chemical reagents; sometimes, with the aid of alkalies or salts appropriate to its nature, he employs the dry way by fire alone; at others, he calls in the solvent power of acids with a digesting heat; happy, if after a series of labours, long, varied, and intricate, he shall finally succeed in separating a notable proportion of one or more metals either in a pure state, or in a form of combination such that from the amount of this known compound, he can infer, with precision, the quantity of fine metal, and thereby the probable value of the mine. The blow-pipe, skilfully applied, affords ready indications of the nature of the metallic constituents, and it is therefore usually the preliminary test. The separation of the several constituents of the ore can be effected, however, only by a chemist, who joins to the most extensive knowledge of the habitudes of mineral substances, much experience, sagacity, and precision in the conduct of analytical operations. Under the individual metals, as also in the articles BLOWPIPE, ASSAY, METALLURGY, MINES, and ORES, are presented such a copious and correct detail of docimatic processes, as will serve to guide the intelligent student through this labyrinth.

DOEGLING TRAIN OIL. The oil of the *Balæna rostrata*, or Bottle-nose whale.

DOGWOOD. *Cornus sanguinea*, a small underwood known as the wild cornel, and as the common Dogwood. Little splinters of this wood are used by the watch-makers for cleaning out the pivot-holes of watches, and by the optician for cleaning deeply-seated small lenses. Its peculiarity is that it is remarkably free from silex. Toothpicks are also manufactured from dogwood.

DOLLY. DOLLY TUB. *A mining term* applied to a tub fitted with a perforated board, *the dolly*, to which a circular motion is given by a winch-handle, and thus imparts a similar motion to the ore. See MINING and ORES, DRESSING OF.

DOLOMITE. Magnesian Limestone. This rock occurs in very great abundance in various parts of England, especially in Yorkshire, Nottinghamshire, and Somerset. It is largely employed as a building stone.

Karsten infers, from his numerous analyses of dolomite, that in those which are crystallised, the carbonate of lime is always combined in simple equivalent proportion with another carbonate, which may be carbonate of magnesia alone, or together with carbonates of iron or manganese, and sometimes both. In the uncrystallised varieties of dolomite, the diversity in the proportion of lime and magnesia is indefinite, but such masses must be regarded as mere mixtures of true dolomite and carbonate of lime. Acids do not produce a perceptible effervescence with dolomite, except when digested with it in fine powder. Karsten found that dilute acetic acid extracts from dolomites, at a temperature below 32° Fahr., only carbonate of lime, while a dolomitic mass remains undissolved. Hence he regards them as mixtures of dolomite with unaltered carbonate of lime. — *Bischof.*

Sulphate of magnesia has been manufactured from dolomite on the large scale.

Dr. William Henry, of Manchester, patented a process of the following kind: — Calcine magnesian limestone so as to expel the carbonic acid; then convert the caustic lime and magnesia into hydrates by moistening them with water; afterwards add a sufficient quantity of hydrochloric, nitric, or acetic acid, or chlorine to dissolve the lime, but not the magnesia, which, after being washed, is converted into sulphate by sulphuric acid, or, where the cost is objectionable, by sulphate of iron, which is easily decomposed by magnesia. Or the mixed hydrates of lime and magnesia are to be added to bittern: chloride of calcium is formed in solution, while two portions of magnesia (one from the bittern, the other from the magnesian lime) are left unacted on. Hydrochlorate of ammonia may be used instead of bittern: by the reaction of this on the hydrated magnesian lime, chloride of calcium and caustic ammonia remain in solution, while magnesia is left undissolved; the ammonia is separated from the decanted liquor by distillation.

In some chemical works on the Tyne, the dolomites from the coast around Marsden are treated with sulphuric acid, and the sulphate of magnesia (*Epsom salts*) separated from the sulphate of lime by crystallisation.

The dolomite has also been employed by the late Hugh Lee Pattinson for the manufacture of the CARBONATE OF MAGNESIA, which see.

DONARIUM. Dr. Bergmann received through Mr. Krantz a mineral from Brerig in Norway, which is found in the same zircon-syenite that contains wöhlerite and eukolite, and he discovered in it the oxide of a new metal combined with silicic acid. This metal he calls *Donarium*, after the god Donar, and he assigns to it the symbol — Do.

The silicate of the oxide of Donarium, $Do^2O^3,SiO^2 + 2HO$, is yellowish red, in some fragments passing into brown, in others into yellow; when scratched or powdered, it is light orange. In thin films it is almost transparent, the thicker ones

translucid. Some pieces have a distinctly laminated structure, in others the fracture is more flat, or conchoidal. Its hardness is between that of fluor spar and apatite; its specific gravity = 5·397.

Small films heated in a platina spoon break down into a dark brown mass, which reassumes an orange colour when cold; the larger pieces lose their transparency. By heating it in a glass tube, watery vapour is driven off. Fragments held by the platina forceps in the flame of a spirit lamp decrepitate. Heated by the blowpipe on charcoal, it does not melt, a slight vitrification being sometimes observed on the edges, perhaps in consequence of the intermixture of some foreign substance. Fused with soda, the silicic acid is dissolved. The other constituents are seen in the non-transparent mass, by the help of a glass, as small yellow particles. Borax yields a yellow bead, which is colourless when cold. The phosphates produce in the external part of the flame a reddish glass, which is colourless when cold; in the inner part of the flame the bead becomes yellow, and when cold is colourless.

The mineral, containing donarium, is readily decomposed by acids, and yields when treated by hydrochloric acid a clear and transparent gelatinous matter. At the same time some carbonic acid is evolved. The colour of the solution is deep yellow, like that of a concentrated solution of iron. The mineral is also affected by diluted acids, even by tartaric acid. After having been exposed to a strong heat, the essential parts of mineral are no longer acted upon even by concentrated acids.

The analysis showed the presence of lime, water, and the new oxide, also some traces of magnesia, manganese, carbonate of soda, and iron.

The oxide of donarium belongs to the class of earthy bodies, and ranks next to zirconia and yttria. The hydrate, which is thrown down by ammonia of a beautiful white colour, becomes yellow, and at last yellowish red, losing its hydrate water in the air. By heat the latter is completely removed, and the oxide, which is insoluble in muriatic acid, can be perfectly deprived by this acid of the contained iron. Analysis showed the constituents to be:—

Silicic acid	17·625
Oxide of donarium	71·247
Carbonate of lime	4·042
Oxide of iron	0·310
Magnesia and oxide of manganese	0·214
Potash and soda	0·303
Water	6·900
	100·641

See *Ure's Dictionary of Chemistry.*

DONKEY ENGINE. A very small engine employed to pump water into boilers. If the use of the donkey engine was more usual than it is we should hear less of steam boiler explosions.

DOOPARA RESIN. A resin obtained in considerable quantities in the East Indies from the *Vateria Indica*, which is used as a fragrant incense in the temples, makes an excellent varnish, and is sometimes called *East Indian Copal*, or *Gum Pincy*. —*Simmonds.*

DORNOCK, is a species of figured linen of stout fabric, which derives its name from a town in Scotland, where it was first manufactured for table-cloths. It is the most simple in pattern of all the varieties of the diaper or damask style, and therefore the goods are usually of coarse quality for common household wear. It receives the figure by reversing the flushing of the warp and woof at certain intervals, so as to form squares, or oblong rectangles upon the cloth. The most simple of these is a succession of alternate squares, forming an imitation of a checker board or mosaic work. The coarsest kinds are generally woven as tweels of three leaves, where every thread floats over two, and is intersected by the third in succession. Some of the finer are tweels of four or five leaves, but few of more; for the six and seven leaf tweels are seldom or never used, and the eight leaf tweel is confined almost exclusively to damask.

DOWN. See FEATHERS. Down *imported* in 1857, 5,208 lbs.

DRAGON'S BLOOD (*Sang dracon*, Fr.; *Drachenblüt*, Germ.) is a resinous substance, which comes to us sometimes in small balls of the size of a pigeon's egg, sometimes in rods, like the finger, and sometimes in irregular cakes. Its colour, in lump, is dark-brown red; in powder, bright red; friable; of a shining fracture; specific gravity 1·196. It contains a little benzoic acid, is insoluble in water, but dissolves readily in alcohol, ether, and oils. It is brought from the East Indies, Africa, South America, as the produce of several trees, the *Dracæna draco*, the *Pterocarpus santalinus*, *Pterocarpus draco*, and the *Calamus rotang.*

Dragon's blood is used chiefly for tingeing spirit and turpentine varnishes, for preparing gold lacquer, for tooth tinctures and powders, for staining marble, &c. According to Herbenger, it consists of 9·07 parts of red resin called *Draconin*, 2 of fixed oil, 3 of benzoic acid, 1·6 of oxalate, and 3·7 of phosphate of lime. According to Johnstone, the resin of lump dragon's blood has the formula $C^{20}H^{21}O^{5}$, that of reed dragon's blood, $C^{20}H^{20}O^{5}$.

Pereira, enumerates the following varieties of this substance found in commerce: —

1. *Dragon's blood in the reed; Dragon's blood in sticks; Sanguis Draconis in baculis.*
2. *Dragon's blood in oval masses; Dragon's blood in drops; Sanguis Draconis in lachrymis.*
3. *Dragon's blood in powder.*
4. *Dragon's blood in the tear; Sanguis Draconis in granis.*
5. *Lump Dragon's blood; Sanguis Draconis in massis.*

Besides these, there are *Dragon's blood in cakes*, and *False Dragon's blood* in oval masses.

DRAINING TILES. Burnt clay tiles, generally shaped in section like a horse shoe, about one foot long and two or three inches broad. These are much used in agricultural draining. See STONE-WARE.

DRAWING CHALKS. Chalks or crayons are frequently nothing more than the natural production reduced to a convenient form: they are, however, sometimes prepared artificially; a few of these manufactures are named.

The brothers Joel, in Paris, employ as crayon cement the following composition: 6 parts of shellac, 4 parts of spirit of wine, 2 parts of turpentine, 12 parts of a colouring powder, such as Prussian-blue, orpiment, white lead, vermilion, &c., and 12 parts of blue clay. The clay being elutriated, passed through a hair sieve, and dried, is to be well incorporated by trituration with the solution of the shellac in the spirit of wine, the turpentine, and the pigment; and the doughy mass is to be pressed in proper moulds, so as to acquire the desired shape. They are then dried by a stove heat.

In order to make cylindrical crayons, a copper cylinder is employed, about 2 inches in diameter, and 1½ inch long, open at one end, and closed at the other with a perforated plate, containing holes corresponding to the sizes of the crayons. The paste is introduced into the open end, and forced through the holes of the bottom by a piston moved by a strong press. The vermicular pieces that pass through are cut to the proper lengths, and dried. As the quality of the crayons depends entirely upon the fineness of the paste, mechanical means must be resorted to for effecting this object in the best manner. The following machine has been found to answer the purpose exceedingly well.

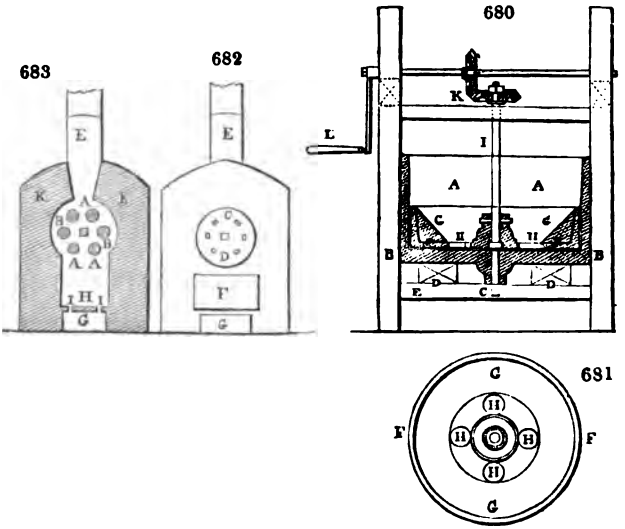
Fig. 680 is a vertical section through the centre of the crayon mill. *Fig.* 681 is a view of the mill from above. A, the mill tub, whose bottom B must be a hard flat plate of cast-iron; the sides A being of wood or iron at pleasure. In the centre of the bottom there is a pivot C, screwed into a socket cast upon the bottom, and which may be strengthened by two cross bars D, made fast to the frame E. F, the millstone of cast-iron, concave, whose diameter is considerably smaller than that of the vessel A; it is furnished within with a circular basin of wood G, which receives the materials to be ground, and directs them tot he holes H, which allows them to pass down between the under part of the muller, and the bottom of the tub, to undergo trituration.

By the centrifugal motion, the paste is driven towards the sides of the vessel, rises over the sides of the muller, and comes again through the holes H, so as to be repeatedly subjected to the grinding operations. This millstone is mounted upon an upright shaft I, which receives a rotatory motion from the bevel-work K, driven by the winch L.

The furnace in which some kinds of crayons, and especially the factitious black-lead pencils, are baked, is represented in *fig.* 682, in a front elevation; and in *fig.* 683, which is a vertical section through the middle of the chimney.

A A, six tubes of greater or less size, according as the substance of the crayons is a better or worse conductor of heat. These tubes, into which the crayons intended for baking are to be put, traverse horizontally the laboratory B of the furnace, and are supported by two plates C, pierced with six square holes for covering the axles of the tubes A. These two plates are hung upon a common axis D; one of them, with a ledge, shuts the cylindrical part of the furnace, as is shown in the figure. At the extremity of the bottom the axis D is supported by an iron fork fixed in the brick-work; at the front it crosses the plate C, and lets through an end about 4 inches square to receive a key, by means of which the axis D may be turned round at pleasure, and thereby the two plates C, and the six tubes A, are thus exposed in succession to the action of the fire in an equal manner upon each of their sides. At the two extremities

of the furnaces are two chimneys E, for the purpose of diffusing the heat more equally over the body of the crayons. F, *fig.* 682, is the door of the fire-place, by which the



fuel is introduced; G, *fig.* 683, the ash-pit; H, the fire-place; I holes of the grate which separate the fire-place from the ash-pit; K, brickwork exterior to the furnace.

General Lomet proposes the following composition for red crayons. He takes the softest hematite, grinds it upon a porphyry slab; and then carefully elutriates it. He makes it into plastic paste with gum arabic and a little white soap, which he forms by moulding, as above, through a syringe, and drying into crayons. The proportions of the ingredients require to be carefully studied.

CRAYONS or CHALKS, *lithographic.* Various formulæ have been given for the formation of these crayons. One of these prescribes white wax, 4 parts; hard tallow-soap, shellac, of each 2 parts; lamp black, 1 part. Another is, dried tallow-soap and white wax, each 6 parts; lamp black, 1 part. This mixture being fused with a gentle heat, is to be cast into moulds for forming crayons of a proper size. See LITHOGRAPHY.

DRUGGET is a coarse, but rather slight, woollen fabric, used for covering carpets, and as an article of clothing by females of the poorer classes.—*Ure.*

The manufacture of druggets of various kinds has been of late years considerably improved, and carpets, many of them handsomely figured, are now found in common use.

DRY GRINDING. The practice of employing dry stones has been long adopted for the purpose of quickening the processes of sharpening and polishing steel goods. The dry dust from the sand-stone, mixed with the fine particles of steel, being inhaled by the workmen, produces diseases of the pulmonary organs to such an extent, that needle and fork grinders are reported rarely to live beyond the ages of twenty-five or thirty.

Mr. Abraham, of Sheffield, first invented magnetic guards, which, being placed close to the grindstone, attracted the particles of steel, and thus protected the men from their influences. Still they suffered from the effects of the fine sand-dust, and the grinders heedlessly abandoned the use of them altogether.

Mr. Abraham devised another plan, which is employed, although only partially, in the Sheffield works. The grindstone is enclosed in a wooden case, which only exposes a portion of the edge of the stone; a horizontal tube proceeds as a tangent from the upper surface of the circle to the external atmosphere. The current of air generated by the stone in rapid revolution, escaping through the tube, carries off with it nearly all the dust arising from the process. It is curious to find so simple a contrivance frequently rejected by the workmen, notwithstanding that sad experience teaches them, that they are thereby exposing themselves to the influences of an atmosphere which produces slowly but surely their dissolution.

DRYING OILS. When oils, especially linseed and nut oils, are boiled with litharge or oxide of lead, they acquire the property of solidifying or *drying* quickly on exposure to the atmosphere. These are very useful to the painter, as without them the pigments with which they are mixed would remain soft. The oxide of lead appears to establish a state of more easy oxidation in the oils, so that they assume readily the conditions of a resin.

DRY ROT. A peculiar decomposition which takes place in wood, dependent upon a process of oxygenation. See WOOD.

DUCTILITY (*Streckbarckeit*, Germ.) is the property of being drawn out in length without breaking, possessed in a pre-eminent degree by gold and silver, as also by many other metals, by glass in the liquid state, and by many semifluid, resinous, and gummy substances. The spider and the silkworm exhibit the finest natural exercise of ductility upon the peculiar viscid secretions from which they spin their threads. When a body can be readily extended in all directions under the hammer, it is said to be malleable, and when into fillets under the rolling press, it is said to be laminable.

Table of the Ductility and Malleability of Metals.

Metals Ductile and Malleable in Alphabetical Order.	Brittle Metals in Alphabetical Order.	Metals in the Order of their Wire-drawing Ductility.	Metals in the Order of their Laminable Ductility.
Cadmium.	Antimony.	Gold	Gold.
Copper.	Arsenic.	Silver.	Silver.
Gold.	Bismuth.	Platinum.	Copper.
Iron.	Cerium ?	Iron.	Tin.
Iridium.	Chromium.	Copper.	Platinum.
Lead.	Cobalt.	Zinc.	Lead.
Magnesium.	Columbium?	Tin.	Zinc.
Mercury.	Iridium.	Lead.	Iron.
Nickel.	Manganese.	Nickel.	Nickel.
Osmium.	Molybdenum.	Palladium?	Palladium?
Palladium.	Osmium.	Cadmium?	Cadmium?
Platinum.	Rhodium.		
Potassium.	Tellurium.		
Silver.	Titanium.		
Sodium.	Tungsten.		
Tin.	Uranium.		
Zinc.			

There appears to be therefore a real difference between ductility and malleability; for the metals which draw into the finest wire are not those which afford the thinnest leaves under the hammer or in the rolling press. Of this fact iron affords a good illustration. Among the metals permanent in the air, 17 are ductile and 16 are brittle. But the most ductile cannot be wire-drawn or laminated to any considerable extent without being annealed from time to time during the progress of the extension, or rather the sliding of the particles alongside of each other, so as to loosen their lateral cohesion.

DULSE. The *Rhodomenia palmata*. See ALGÆ.

DUNES. Low hills of blown sand, which are seen on the coasts of Cheshire and Cornwall, in this country, and also in many places skirting the shores of Holland and Spain.

DUNGING, in calico-printing, is the application of a bath of cowdung, diffused through hot water, to cotton goods in a particular stage of the manufacture. Dunging and scouring are commonly alternated, and are two of the most important steps in the process. See CALICO PRINTING.

DUTCH LEAF or FOIL, a composition of copper and lime, or of bronze and copper leaf. See ALLOYS, BRASS, and BRONZE POWDERS.

DUTCH RUSH. *Equisetum Hyemale*. This rush is known also as the *Large branchless Horse-tail*. The dried stems are much employed for polishing wood and metal. For this purpose they are generally imported from Holland.

DYEING (*Teinture*, Fr.; *Färberei*, Germ.) is the art of imparting to and fixing upon wool, silk, cotton, linen, hair, and skins any colour, with sufficient tenacity, not to be removed by water or the ordinary usage to which these fibrous bodies are exposed when worked up into articles of raiment or furniture. We shall here consider the general principles of the art, referring, for the particular dyes and the manner of

opening from the chambers outwards, is opened, in order that, the air escaping, an uninterrupted flow of water may take place into the chambers. The weight of water entering the chambers causes a destruction of the buoyancy of the machine, and the nautilus gradually sinks. As soon as it is fairly under water, in order that the descent may be quiet and without shock, the water-cock *b*, is closed. The receiver at the surface being previously charged by the air pump to a density somewhat greater than that of the water at the depth proposed to attain, one of the branch-cocks on the pipe *c c*, connecting the chambers at top, is opened, and the air rushes into the working chamber, gradually condensing until a density equal to the density of the water without is attained; this is indicated by proper air and water gauges. These gauges marking equal points, showing the equilibrium of forces without and within, the cover to the bottom *z* is removed or raised, and communication is made with the under water surface, on which the nautilus is resting. In order to move about in localities where tides or currents do not affect operations, it is only necessary for the workman to step out of the bottom of the nautilus, and placing the hands against its sides, the operator may move it (by pushing) in any direction.

Where currents or tides, however, have sway, it becomes necessary to depend upon fixed points from which movements may be made in any direction. This is accomplished by placing, in the bottom of the nautilus, stuffing boxes of peculiar construction (m m, *fig.* 672), through which cables may pass over pulleys to the external sides, thence up through tubes (to prevent their being worn), to and over oscillating or swinging pulleys, placed in the plane of the centre of gravity of the nautilus, and thence to the points of affixment respectively (*fig.* 673). The object to be gained by having

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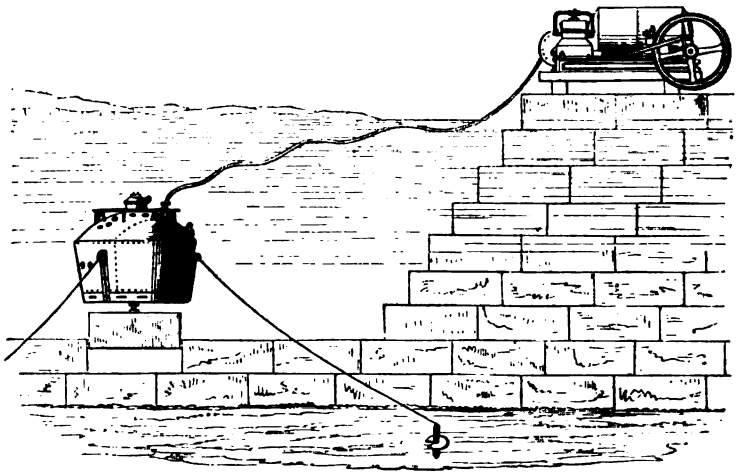


the swinging pulleys in the plane of the centre of gravity of the mass, is to hold the machine steady and to prevent oscillation. Within the machine, and directly over the above stuffing boxes, are windlasses for winding in the cables. By working these windlasses movement may be effected, and of course the number of these cables will depend on the variable character of the situation to be occupied. Having thus secured the means of descending, communicating with the bottom, and of movement, the next point is to ascend. Weight of water has caused a destruction of buoyancy at first, and consequent sinking; if then any portion of this water is removed, an upward effort will at once be exerted exactly proportionate to the weight of water thrown off. The air in the receiver at the surface being constantly maintained at a higher density than that of the water below, if we open the water cock on the top pipe, *c, c*, throwing the condensed air from the receiver above directly on to the surface of the water in the chambers, movement and consequent expulsion of the water must take place, and an upward movement of the machine itself, which will rise to the surface.

It is evident that if, previously to the expulsion of the water, the nautilus be affixed to any object below, the power exerted on that object will be exactly proportionate to the weight of water expelled, and the power will continue increasing until, there

being no farther weight to be thrown off, the maximum effect is produced. To apply this power to lifting masses of stone or rock, proper arrangements are affixed to the centre of the opening in the bottom, by which connection can be made with the weight, admitting, at the same time, the swinging around of the object suspended, so that it may be placed in any required position. In the construction of permanent work, or the movement of objects whose weight is known, or can be estimated, a water, or, so called, lifting tube is placed on the side of the water chamber, which indicates the lifting power exercised by the nautilus at any moment. The advantage of this gauge will be recognised, inasmuch as without it the closest attention of the operator, working very cautiously, would be necessary to determine when the weight was overcome; by its aid, however, the operator boldly throws open all the valves necessary to develope the power of the nautilus, watching only the gauge. The water, having reached the proper level indicating the required lifting power, he knows the weight must be overcome, or so nearly so that the valve or cocks may be at once closed, in order that the movement may take place horizontally. A moment's reflection will show that, if there were not an index of this character, carelessness or inattention on the part of the operator, by leaving the cocks open too long, might develope a power greater than required, and the nautilus would start suddenly upward. The expansive power of air, acting upon the incompressible fluid, water, through the opening in the bottom, gives a momentum which, by successive developments of expansion in the working chamber, is constantly increasing in velocity, until, in any considerable depth of water, the result would be undoubtedly of a very serious character. Take, for exemplification, the nautilus in thirty-three feet of water, and bottom covers removed, and an equilibrium, at fifteen pounds to the inch, existing between the air and the water at the level of the bottom of the machine. Upward movement is communicated the instant the machine rises in the slightest degree, the existing equilibrium is destroyed, and the highly elastic qualities of air assume preponderance, exerting, from the rigid surface of the water below, an impulsive effort upward in the direction of least resistance. At each successive moment of upward movement the impelling power increases, owing to the increasing disparity between the pressure of air within struggling for escape. The machine, thus situated, becomes a marine rocket (in reality), in which the propelling power is exhausted only when the surface is reached, and a new equilibrium is obtained. It will readily be seen that, were this difficulty not overcome, it would be impossible to govern the nautilus; for, rising with great velocity to the surface, the machine is carried above its ordinary flotation, or water line, a little more air escaping owing to the diminished resistance as that level is passed; the recoil, or surging downwards, causes a condensation of the air remaining in the chamber; a portion of the space previously occupied by air is assumed by water; the buoyant power becomes less, the machine settles slightly more by condensation of the air, a larger space is occupied by water, and the nautilus redescends to the bottom with a constantly accelerating movement, seriously inconveniencing the operator by filling more or less with water, according to depth. For many months the difficulties just enumerated baffled all attempts at control. A weight attached could be lifted, but the instant it was entirely suspended, — before the valves could be closed, — upward movement was communicated beyond control. This difficulty so fatal has been overcome by an arrangement at the bottom of the nautilus, with channels which radiate from the opening in an inclined direction, debouching at the sides of the machine. The moment then that the air, by its expansion from diminished resistance, or by the introduction from above of a greater volume than can be sustained by the water below, reaches, in its downward passage, the level of these chambers, following the direction of least resistance, it passes through these channels and escapes into the surrounding water, without of course affecting the movement of the machine in the least.

The pump for supplying air to the diving bell or other suitable vessel is represented at *figs.* 674 and 675, and is constructed as follows: — D is a cylinder, opening at the upper part into a chamber or chambers F F, separated by a partition E. On the side of each of these chambers there is a valve H H, opening inwards, and at the upper part of the same are two valves I I, opening outwards into the valve chamber G. Outside the opening for each of the valves H, H, there is a cup, into which the end of the water supply pipe M passes; by this means a small stream of water is supplied to the cup, and is drawn from it into the chamber F to supply the waste in the operation of pumping. The valve chamber G is covered with a jacket *k*, having a space between it and the valve chamber that is filled with water from the water pipe M, which affords a stream of cold water to carry off the heat from the condensed air which is forced into the chamber. The water thus supplied circulates through the tubes in the chamber and round them in the jacket, and thus cools the air in these

nounced as a dangerous drug, and forbidden to be used, by our parliament in the reign of Queen Elizabeth. An act was passed authorising searchers to burn both it and logwood in every dye-house where they could be found. This act remained in full force till the time of Charles II.; that is, for a great part of a century. A foreigner might have supposed that the legislators of England entertained such an affection for their native woad, with which their naked sires used to dye their skins in the old times, that they would allow no outlandish drug to come in competition with it. A most instructive book might be written illustrative of the evils inflicted upon arts, manufactures, and commerce, in consequence of the ignorance of the legislature."

More recently another class of dye-drugs have been introduced, and have superseded some of those of the former century; these are bichromate of potash, red and yellow prussiate of potash, manganese, catechu, arsenic, &c.

Colours are not, properly speaking, material; they are impressions which we receive from the rays of light reflected, in a decomposed state, by the surfaces of bodies. It is well known that a white sunbeam consists of an indeterminate number of differently coloured rays, which, being separated by the refractive force of a glass prism, form the solar spectrum, an image divided by Newton into seven sorts of rays; the red, orange, yellow, green, blue, indigo, and violet. Hence, when an opaque body appears coloured, for example, red, we say that it reflects the red rays only, or in greatest abundance, mixed with more or less of the white beam, which has escaped decomposition. According to this manner of viewing the colouring principle, the art of dyeing consists in fixing upon stuffs, by means of corpuscular attraction, substances which act upon light in a different manner from the surfaces of the stuffs themselves. The dyer ought, therefore, to be familiar with two principles of optics; the first relatively to the mixture of colours, and the second to their simultaneous contrast.

Whenever the different coloured rays, which have been separated by the prism, are totally reunited, they reproduce white light. It is evident, that in this composition of light, if some rays were left out, or if the coloured rays be not in a certain proportion, we should not have white light, but light of a certain colour. For example; if we separate the red rays from the light decomposed by a prism, the remaining coloured rays will form by their combination a peculiar bluish green. If we separate in like manner the orange rays, the remaining coloured rays will form by their combination a blue colour. If we separate from the decomposed prismatic light the rays of greenish yellow, the remaining coloured rays will form a violet. And if we separate the rays of yellow bordering on orange, the remaining coloured rays will form by their union an indigo colour.

Thus we see that every coloured light has such a relation with another coloured light that, by uniting the first with the second, we reproduce white light; a relation which we express by saying that the one is the complement of the other. In this sense, red is the complementary colour of bluish green; orange, of blue; greenish yellow, of violet; and orange yellow, of indigo. If we mix the yellow ray with the red, we produce orange; the blue ray with the yellow, we produce green; and the blue with the red, we produce violet or indigo, according as there is more or less red relatively to the blue. But these tints are distinguishable from the orange, green, indigo, and violet of the solar spectrum, because when viewed through the prism they are reduced to their elementary component colours.

If the dyer tries to realise the preceding results by the mixture of dyes, he will succeed only with a certain number of them. Thus, with red and yellow he can make orange; with blue and yellow, green; with blue and red, indigo or violet. These facts, the results of practice, have led him to the conclusion that there are only three primitive colours; the red, yellow, and blue. If he attempts to make a white, by applying red, yellow, and blue dyes in certain quantities to a white stuff, in imitation of the philosopher's experiment on the synthesis of the sunbeam, far from succeeding, he will deviate still further from his purpose, and the stuff will by these dyes become coloured of a depth varying according to the quality of the stuff used; until a full black is produced. Nevertheless, the principle is applicable, and in many cases adopted in practice by blending the yellow, red, and blue rays in order to produce or improve an otherwise imperfect white. When a little ultramarine, cobalt blue, prussian blue, or indigo is applied to bleached goods with the view of giving them the best possible white, if only a certain proportion be used, the goods will appear whiter after this addition than before it. In this case the violet blue forms with the brown yellow of the goods a mixture tending to white, or less coloured than the yellow of the goods and the blue separately were. For the same reason a mixture of prussian blue and cochineal pink, or archil and cudbear, is used for whitening of silks in preference to a pure blue, for on examining closely the colour of the silk to be neutralised, it was found by the relations of the complementary colours, that the violet was more suitable than the pure blue alone. The dyer should know, that

when he applies several different colouring matters to stuff, as yellow and blue separately, they will appear green, not because the colouring matters have combined, but because the eye cannot distinguish the points which reflect the yellow from those which reflect the blue, and it is this want of distinction that produces the combined colour. With such a dye the colour will appear of different tints, the blue or yellow prevailing according to the position in which it is placed to the eye, whether seen by reflected or transmitted, light, but when the dye applied to the stuff is in chemical union, producing a green, such as arsenite of copper the yellow and blue rays cannot be thus distinguished. Other instances of mixed colours will be seen by examining certain grey substances, such as hairs, feathers, &c. with the microscope, by which it is seen grey colour results from black points disseminated over a colourless or slightly coloured surface. The microscope may be thus usefully applied by the dyer to distinguish whether a colour be the result of a mixed or a combined dye.

The dyer should also be acquainted with the law of the simultaneous contrast of colours. When the eye views two colours close alongside of each other, it sees them differing most, in the height of their tone, when the two are not equally pale or full-bodied. They appear most different, when the complementary of the one of them is added to the colour of the other. Thus, put a green alongside of an orange, the red colour complementary of green being added to the orange, will make it appear redder. And in like manner, the blue complementary of orange being added to the green, will make it appear more intensely blue.

It is not sufficient to place complementary colours side by side to produce harmony of colour, the respective intensities having a most decided influence; thus, pink and light green agree, red and dark green also; but light green and dark red, pink and dark green do not, therefore, to obtain the maximum of effect and perfect harmony, the following colours must be placed side by side, taking into account their exact intensity and tint.

Primitive Colour.	Secondary Colours.	
Red	Green	Light blue, Yellow, Red
Blue	Orange	Red, Yellow, Blue
Yellow orange	Indigo	Blue, Red, Yellow
Greenish yellow	Violet	Red, Blue, Yellow
Black	White	Yellow, Blue, Red

The mixed contrast gives the reason why a brilliant colour should never be looked at for any length of time, if its true tint or brilliancy is to be appreciated; for if a person looks, for example, at a piece of red cloth for a few minutes, green, its complementary colour is generated in the eye, and adding itself to a portion of the red, produces black, which tarnishes the beauty of the red. This contrast explains why the shade of a colour, may be modified according to the colour which the eye has previous looked at, either favourably or otherwise. An example of the first instance is noticed, when the eye first looks to a yellow substance, and then to a purple one; and as exemplifying the second case looking at a blue and then at a purple.

The relations of dyeing with the principles of chemistry, constitute the theory of the art, properly speaking; this theory has for its basis the knowledge —

1st. Of the nature and properties of the bodies which dyeing processes bring into contact.

2nd. Of the circumstances in which these bodies are brought together, facilitating or retarding their action.

3rd. The phenomena which appear during their action; and,

4th. Properties of the coloured combinations which are produced.

The first of these generalities embrace a knowledge of the preparations, which stuff necessarily undergoes previous to dyeing, and also the preparations of the dye-drug before bringing it into contact with the stuff.

The operations to which stuffs are subjected before dyeing, are intended to separate from them any foreign matters which may have become attached, or are naturally

inherent in the stuff. The former are such as have been added in the spinning, weaving, or other manipulations of the manufacture, and are all removed by steeping in an alkaline lye and washing. The second are the natural yellow colouring substances which coat some of the various fibres, both vegetable and animal; and the chlorophylle, or leaf-green of vegetables. The removal of these is generally effected by boiling in soap and alkaline lyes. A weak bath of soda, in which the stuff is allowed to steep for some time, and then washed in water, is generally the only preparation required for wool, in order that it may take on a uniform dye.

To remove the gummy or resinous matter from silk, it requires boiling in soap lye; however, its removal is not essential to the stuff combining with the dye, as silk is often dyed while the gum remains in it, in which case it is only rinsed in soap lye at a very moderate heat, to remove any foreign matters imbibed in the process of manufacture.

Vegetable fibre, as cotton, has such natural resinous matters that retard the reception of the dye removed by boiling, either with or without alkaline lyes; but the natural dun colour of the fibre is not removed, which from the laws of light and colour already referred to, would interfere with the production of bright light tints; under these circumstances, the natural colour of the fibre has to be previously removed by bleaching, for which see the article, BLEACHING.

The necessary preparation of the dye-drugs within the province of the dyer, is to obtain the colour in a state of solution, so as to allow the fibre to absorb it, and to produce chemical combination, or to get the dye or colour in such a minute state of division as it will penetrate or enter into the fibre of the stuff. These preparations embrace the formation of decoctions, extracts, and solutions, and also in some cases of precipitation, previous to immersing the stuff into the bath. Stuffs, chemically considered, have but a feeble attraction for other matters, so as to combine with them chemically; still that they do possess certain attractions is evident from various phenomena observed in the dyeing processes, and that this attraction is possessed with different degrees of intensity by the different fibres, is also evident from the ease and permanence that woollen stuff will take up and retain dyes compared with cotton; and also, that certain dyes are retained and fixed within or upon one kind of fibre and not at all in another. This may be determined by plunging the dry stuff into solutions of the salts, and determining the density of the solution before the immersion and after withdrawing the stuff. Wool abstracts alum from its solution, but it gives it all out again to boiling water. The sulphates of iron, copper, and zinc, resemble alum in this respect. Silk steeped for some time in a solution of protosulphate of iron, abstracts the oxide, and gets thereby dyed, and leaves the solution acidulous. Cotton in nitrate of iron produces the same effect. Wool put in contact with cream of tartar, decomposes a portion of it; it absorbs the acid within its pores, and leaves a neutral salt in solution in the liquor. Cotton produces no such effect with tartar, showing by these different effects that there are certain attractions between the stuff and dyes. This attraction, however, may be more what is termed a catalytic influence, the fibres of the stuff producing a chemical action with the salt or dye, with which it is in contact. This attraction or affinity of the fibre for the dye-drug, does not produce a very extensive effect in the processes of dyeing. More probably the power of imbibing and retaining colours possessed by the fibre is more dependent upon a mechanical than a chemical influence.

All dye-drugs must in the first instance be brought into a state of solution, in order that the dye may be imbibed by the fibre; but if the fibre exerts no attraction for the colour so as to retain it, it is evident that so long as it remains capable of dissolving in water, the stuffs being brought into contact with water, will soon lose their colour. A colour thus formed does not constitute a dye, however strongly stained the stuffs may appear to be, in or out the dyeing solution; in order to form a dye, the colour must be fixed upon or within the stuff, in a condition insoluble in water. Hence the mere immersion of the stuff into a solution of a colour will not constitute a dye, except where the stuff really has an attraction for the colour and retains it, or causes a decomposition by which an insoluble compound is fixed upon it, such as referred to by putting stuffs into solutions of iron. The abstraction of the colour from a solution by the immersion of the stuff, is often the result of a mechanical attraction possessed by porous substances, enabling them to absorb or imbibe certain colouring matters from solutions that are held by a weak attraction by their solvents. On this principle, a decoction of cochineal, logwood, brazil-wood, or a solution of sulphate of indigo, by digestion with powdered bone black, lose their colour, in consequence of the colouring particles combining by a kind of capillary attraction with the porous carbon, without undergoing any change. The same thing happens when well scoured wool is steeped in such coloured liquids; and the colour which the wool assumes by its attraction for the dye, is, with regard to most of the above coloured solutions, but feeble and fugitive, since the dye may be again abstracted by copious washing with

simple water, whose attractive force therefore overcomes that of the wool. The aid of a high temperature, indeed, is requisite for the abstraction of the colour from the wool and the bone-black, probably by enlarging the size of the pores, and increasing the solvent power of the water.

Those dyes, whose colouring matter is of the nature of extractive, form a faster combination with stuffs. Thus the yellow, fawn, and brown dyes, which contain tannin and extractive, become oxygenated by contact of air, and insoluble in water; by which means they can impart a durable dye. When wool is impregnated with decoctions of that kind, its pores get charged by capillarity, and when the liquid becomes oxygenated, they remain filled with a colour now become insoluble in water. The fixation of iron oxide and several other bases also depends on the same change within the pores or fibre, hence all salts that have a tendency to pass readily into the basic state are peculiarly adapted to act as a medium for fixing dyes; however, this property is not essential.

In order to impart to the stuffs the power of fixing the colour in an insoluble form upon it, recourse is had to other substances, which will combine with the soluble and form with it an insoluble colour; and it is not necessary that this new substance should have an attraction for the stuff, or be capable of passing into a basic form, any more than the original colour, but it is necessary that it be rendered insoluble while in contact with the stuff.

Such substances used to unite the colour with the stuff have been termed mordants, which meant that they had a mutual attraction for the stuff and colour, and combining with the stuff first, they afterwards took up the colour; but this is only so in some instances. A few examples will illustrate the bearing of these mordants. If a piece of cotton stuff is put into a decoction of logwood, it will get stained of a depth according to the colour of the solution, but this stain or colour may be washed from the cotton by putting it into pure water, the colour being soluble. If another piece of cotton stuff be put into a solution of protosulphate of iron, and then washed from this, a portion of the iron will have undergone oxidation, and left the acid, and become fixed upon the fibre and insoluble in water. Whether this oxidation is the result of an influence of the stuff, or the effect of the oxygen of the air and water in which the goods are exposed, it does not matter meantime, only this fixed oxide constitutes an example of a mordant by its combining with the stuff. If this stuff is now put into a decoction of logwood, the colouring matter of the logwood will combine with the oxide of iron fixed upon the fibre, and form an insoluble colour, which after washing will not remove from the stuff. If, instead of washing the stuff from the sulphate of iron solution in water, it be passed through an alkaline lye of soda or potash, the acid holding the iron in solution is taken hold of by the alkali, and removed. The oxide of iron is thus left upon the stuff, in a much larger quantity than in the former case, and as firmly fixed, although not by any attraction between it and the fibre, but simply being left within it. And this stuff being now put into the logwood liquor, will form a dye of a depth according to the quantity of iron thus fixed upon the stuff, and equally permanent with that which had been fixed on the stuff by the oxidation in working.

Such then are the methods of fixing within the stuff insoluble colours from soluble compounds, and from these remarks the necessity of having the dye in solution will also be evident.

Suppose again that the sulphate of iron be mixed with the logwood decoction, there will be produced the same colour or dye as an insoluble precipitate: if the cotton stuff is put into this, no colour worthy of the name of a dye will be obtained, as the cotton will not imbibe within its fibre this precipitate. Place woollen stuff in the same liquid, there is formed a very good dye, the woollen fibre having imbibed a great portion of the solid precipitate, probably owing to woollen fibres being much larger than those of cotton. Thus, with cotton and other stuff that will not imbibe freely solid precipitates, the mordant must be fixed within the fibre previous to applying the colouring substances, such as the vegetable decoctions. It will also be seen that the dye which is the product of combination between the mordant and colour is not that of the natural colour of the drug, but the colour of the compound. Hence the great variety of tints capable of being produced from one dye-drug, by varying either the kind or intensity of the mordant. So that in the above instances, it is not the colour of the hematoxylin fixed on the stuff, but its compound with iron, or tin, or alumina, as the case may be, all of which give different tints.

It is upon this principle of rendering bases insoluble while within the fibre by chemical means, that has brought to the use of the dyer a great number of mineral dyes which in themselves, whether separate or combined, have no attraction whatever for the fibre; such as solutions of sulphate of copper, and yellow prussiate of potash, nitrate of lead, and bichromate of potash, &c. Suppose the stuff to be dyed a yellow

by the two last named salts, was first put into the solution of lead and then washed previous to being put into the bichromate solution, the greater portion of the lead would be dissolved from the stuff, and a very weak colour would be obtained. If the stuff from the lead solution was put directly into the bichromate solution, a very good dye would be the result; but the portion of the solution remaining upon the surface of the stuff will combine with the chrome and form a precipitate which the fibre cannot imbibe, but will form an external crust or pigment upon the surface, which blocks up the pores, and exhausts to no purpose the dye, causing great waste: hence the stuff from the solution of lead is put into water containing a little soda or lime, and the lead is thus reduced to an insoluble oxide within the fibre. The goods may now be washed from any loose oxide adhering, and then passed through the bichromate solution, when the chromic acid combines with the oxide of lead, forming a permanent yellow dye. Thus it will be seen that whether the combination of the colour with the stuff be chemical or mechanical the production of the dye which is fixed upon the fibre is certainly a chemical question, and the dyer should be familiar with the nature and principles of these reactions.

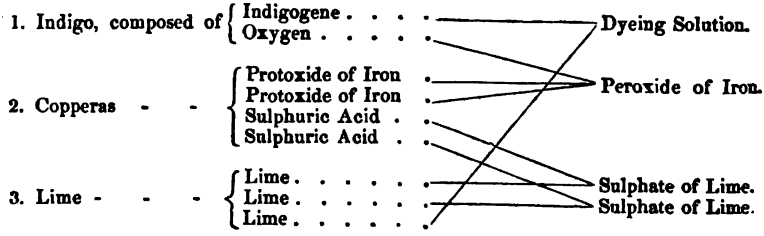
There are a few instances where the dye produced does not come within the sphere of these principles, there being no mordants required, nor any combination of the colour formed within the stuff, but the dye-drug in its natural hue is fixed within the fibre. Such colours have been termed *substantive*, to distinguish them from those produced by means of mordants, which are termed *adjective*. Amongst this class of dyes and dye-drugs stands pre-eminent indigo blue. Indigo in its natural state is entirely insoluble in water, and is of a deep blue colour. The composition of this blue indigo is represented as —

Carbon - - -	16	Nitrogen - -	1
Hydrogen - -	5	Oxygen - - -	2

But it is found capable of parting with a portion of the oxygen, and by so doing, losing entirely its blue colour; and in this deoxidised condition it is soluble in alkaline lyes and lime water; this colourless compound is termed indigogene. The opinion of Liebig upon the constitution of this substance is, that indigo contains a salt radical, which he terms *Anyle*, composed of $C^{16}H^5N$. He considers that indigogene or white indigo is the *hydrated* protoxide of this radical, and that blue indigo is the peroxide, represented thus —

	C	H	N	O	Water.
Salt radical, anyle - - -	16	5	1	0	0
Indigogene - - - -	16	5	1	1	1
Blue indigo - - - -	16	5	1	2	0

Advantage is taken of this property of indigo, of parting with its oxygen and becoming soluble, to apply it to dyeing, and it is effected by the following means, when for the purpose of dyeing vegetable stuff, as cotton; and from the circumstance of these operations being done cold, the method is termed the cold vat, which is made up as follows:—The indigo is reduced to an impalpable pulp, by being ground in water to the consistence of thick cream. This is put into a suitable vessel filled with water, along with a quantity of copperas, and newly slaked lime, and the whole well mixed by stirring. After a short time the indigo is deoxidised and rendered soluble by a portion of the lime which is added in excess, the reaction being represented thus:—



The peroxide of iron and sulphate of lime are precipitated to the bottom, and the indigogene and lime form a solution of a straw colour, with dark veins through it.

The operation of dyeing by this solution is simply immersion, technically, *dipping*. The stuff by immersion imbibes the solution, and when taken out and exposed to the air, the indigogene upon and within the fibre rapidly takes oxygen from the atmosphere, and becomes indigo blue, thus forming a permanent dye, without any necessary attraction between the indigo and the stuff.

The indigo vat for wool and silk is made up with indigo pulp, potash, madder, and

bran. In this vat the extracts of madder and bran perform the deoxidising functions of the copperas in the cold vat, by undergoing a species of fermentation.

Pastel and wood, either alone or with the addition of a little indigo, is also used for the dyeing of wool and silk stuff, the deoxidation being effected by the addition of bran, madder and weld. In dyeing with these vats, the liquor is made warm, and they require much skill and experience to manage, in consequence of their complexity, being always liable to go out of condition, as the dyeing goes on, by the extraction of the indigogene and the modification of the fermentable matter employed to deoxidise the indigo to supply that loss. The alkaline solvent also undergoes change, so there must be successive additions of indigo and alkali; the principal attention of the dyer is the maintaining the proper relation of these matters, as too much or too little of either is injurious.

Sulphate of indigo forms an intense blue solution, unaffected also by mordants. Vegetable stuffs dipped in this retain no dye, for the washing off the acid in order to preserve the fibre removes the colour; but animal fibre, such as woollen and silk, becomes dyed; a portion of the blue remains upon the stuff after washing off the acid, being retained by capillary attraction. This dye is termed Saxon blue, but it has very little of the permanence of indigo or *vat blue*, although it is also a substantive colour.

Another truly substantive colour is that dyed by carthamus or safflower, but the fixation of this dye upon the stuff differs from any of those referred to. Like indigo, it has no affinity for any base or substance capable of forming a mordant; its solvent is an alkali, but in this dissolved state it does not form a dye. The mode of proceeding in dyeing with carthamus is first to extract the dye from the vegetable in which it is found, by soda or potash, which is afterwards neutralised by an acid previous to dyeing, which renders the colour insoluble, but in so fine a state of division that no precipitation can be seen for some time and the stuff immersed in this imbibes the colour within its fibre, its lightness assisting this action, as the precipitate will remain suspended in water for days before it will subside. Vegetable fibre takes up this dye as easily as animal, but whether by an attraction for the stuff, or by a mechanical capillary attraction of the fibre is not so easily determined. A piece of stuff suspended in a vessel filled with water, having in it some insoluble carthamine, all the colouring particles will flow to and combine with the fibre from a considerable distance, giving a proof of the existence of some force drawing them together.

Such then are the various conditions and principles involved in the processes of fixing the dye within or upon the stuff.

During the operations of dyeing there are certain circumstances which have to be attended to, in order to facilitate and effect certain hues or tints of colour. Thus, with many of the colouring substances, heat not only favours but is necessary for the solution of the dye, and also its combination with the stuff or mordant. Decoctions of woods are always made by hot water, and the dyeing processes with decoctions are in hot liquor. When the colouring matter of quercitron bark is extracted by boiling water, the colour produced upon the stuff will be a rich amber yellow, but if the extract be made by water at 180° Fahr., a beautiful lemon yellow will be the dye produced by it, using the same mordant in each case. Colours dyed by madder and Barwood must be done at a boiling heat during the whole process, or no dye is effected. Sumach, another astringent substance, is most advantageously applied at a boiling heat; and in order to have a large body of this dye fixed upon the stuff, it should be immersed in the liquor while hot and allowed to cool together, during which the tannin of the dye undergoes some remarkable change in contact with the stuff. Safflower dyes are kept cold, so are tin bases, Prussian blues, and chrome yellows: by applying heat to the last a similar result is effected to that with bark; instead of a lemon yellow an amber yellow will be obtained. Almost all colours are affected less or more by the temperature at which they are produced. Some mordants are fixed upon the stuff by heat, such as acetate of alumina; the stuff being dried from a solution of this salt at a high temperature loses part of the acid by being volatilised, and there remains upon the fibre an insoluble suboxide, which fixes the dye. These remarks respecting the methods apply more particularly to vegetable stuffs, as cotton, and in many cases also to silk, but wool is always dyed at a high heat. Although wool seems to have a much greater absorbing power than cotton, the latter will absorb and become strongly dyed in a cold dye bath, in which wool would not be affected; but apply heat and the wool will be deeply dyed, and the dye much more permanent than the cotton.

The permanence of colours is another property to be carefully studied by the practical dyer, as the colour must not be brought under circumstances that will destroy its permanency during any of the operations of the dyehouse. The word permanent, however, does not mean *fast*, which is a technical term applied to a colour that will resist all ordinary operations of destruction. As for instance, a Prussian

blue is a permanent colour but not a fast colour, as any alkaline matter will destroy it, or a common black is permanent, although any acid matters will destroy it; while Turkey red is a fast colour and not affected by either acid or alkaline matters. A few of the circumstances affecting colours in the processes they are subjected to may be referred to in this place. If, for instance, the air in drying the dyed stuff in a hot chamber be moist, there is a great tendency to the colour being impaired in these circumstances. For example, a red colour dyed with safflower will pass into brown, a Prussian blue will pass into a grey lavender, chrome yellows take an amber tint. Mostly all colours are affected less or more by being subjected to strong heat and moisture; even some of those colours termed fast are affected under such circumstances. A dry heat has little or no effect upon any colour, and a few colours are made brighter in their tint by such a heat, as chrome orange, indigo blue, on cotton, &c.

Some of these effects of heat and moisture differ with different stuff; thus indigo blue upon cotton is not so much affected as indigo blue upon silk, while safflower red upon cotton will be completely destroyed before the same colour upon silk will be perceptibly affected. The same colouring matter fixed by different mordants upon the same stuff is also differently affected under these conditions.

Light is another agent effecting a great influence upon the permanence of colours, which should be also considered by the dyer. Reds dyed by a Brazil wood and a tin mordant, exposed to the light, become brown; Prussian blue takes a purple tint; yellow becomes brownish; safflower red, yellowish, and these changes are facilitated by the presence of moisture; such as exposing them to strong light while drying from the dye bath, either out or within doors. The direct rays of the sun destroy all dyed colours; even Turkey red yields before that agency.

Boiling was formerly prescribed in France as a test of fast dyes. It consisted in putting a sample of the dyed goods in boiling water, holding in solution a determinate quantity of alum, tartar, soap, and vinegar, &c. Dufay improved that barbarous test. He considered that fast-dyed cloth could be recognised by resisting an exposure of twelve hours to the sunshine of summer, and to the midnight dews; or of sixteen days in winter.

In trying the stability of dyes, we may offer the following rules: —

That every stuff should be exposed to the light and air; if it be intended to be worn abroad, it should be exposed also to the wind and rain; that carpets moreover should be subjected to friction and pulling, to prove their tenacity; and that cloths to be washed should be exposed to the action of hot water and soap. However, such tests are not at all applicable to most of the colours dyed upon cotton stuff. Not many of them can stand the action of hot water and soap, or even such acids as the juice of fruits. Indigo blue, one of the most permanent dyes on cotton, yields its intensity to every operation of washing, even in pure water.

Delaval's observations on the nature of dyes may be thus summed up. In transparent coloured substances, the colouring substance does not reflect any light; and when, by intercepting the light which was transmitted, it is hindered from passing through substances, they do not vary from their former colour to any other colour, but become entirely black; and he instances a considerable number of coloured liquors, none of them endued with reflective powers, which, when seen by transmitted light, appeared severally in their true colours; but all of them, when seen by incident light, appeared black; which is also the case of black cherries, black currants, black berries, &c., the juices of which appeared red when spread on a white ground, or otherwise viewed by transmitted instead of incident light; and he concludes, that bleached linen, &c. "when dyed with vegetable colours, do not differ in their manner of acting on the rays of light, from natural vegetable bodies; both yielding their colours by transmitting, through the transparent coloured matter, the light which is reflected from the white ground:" it being apparent, from different experiments, "that no reflecting power resides in any of their components, except in their white matter only," and that "transparent coloured substances, placed in situations by which transmission of light through them is intercepted, exhibit no colour, but become entirely black."

The art of dyeing, therefore (according to Mr. Delaval), "consists principally in covering white substances, from which light is strongly reflected, with transparent coloured media, which, according to their several colours, transmit more or less copiously the rays reflected from the white," since "the transparent media themselves reflect no light; and it is evident that if they yielded their colours by reflecting instead of transmitting the rays, the whiteness or colour of the ground on which they are applied would not in anywise alter or affect the colours which they exhibit."

But when any opaque basis is interposed, the reflection is doubtless made by it,

rather than by the substance of the dyed wool, silk, &c., and more especially when such basis consists of the white earth of alum, or the white oxide of tin; which, by their strong reflective powers, greatly augment the lustre of colours. There are, moreover, some opaque colouring matters, particularly the acetous, and other solutions of iron, used to stain linen, cotton, &c., which must necessarily themselves reflect instead of transmitting the light by which their colours are made perceptible.

The compound or mixed colours are such as result from the combination of two differently coloured dye stuffs, or from dyeing stuffs with one colour, and then with another. The simple colours of the dyer are red, yellow, blue, and black, with which, when skilfully blended, he can produce every variety of tint. Perhaps the dun or fawn colour might be added to the above, as it is directly obtained from a great many vegetable substances.

1. Red with yellow, produces orange; a colour, which upon wool is given usually with the spent scarlet bath. To this shade may be referred flame colour, pomegranate, capuchin, prawn, jonquil, *cassis*, chamois, *café au lait*, aurora, marigold, orange peel, *mordorés*, cinnamon, gold, &c. Snuff, chestnut, musk, and other shades are produced by substituting walnut peels or sumach for bright yellow. If a little blue be added to orange, an olive is obtained. The only direct orange dyes are annotto, and subchromate of lead. See SILK and WOOL DYEING.

The latter is never used for dyeing orange upon silk and wool, while the former is now never used for cotton. An orange with annotto is very fugitive, even upon the animal fibre; but much more so upon cotton. Subchromate of lead is produced upon cotton by dyeing it first a deep chrome yellow by acetate of lead and bichromate of potash, as already noticed, and then passing the stuff so dyed through a hot solution of an alkali or lime, which changes the dye from the yellow chromate to the state of subchromate, which is deep orange.

2. Red with blue produces purple, violet, lilac, pigeon's neck, mallow, peach-blossom, *bleu de roi*, lint-blossom, amaranth.

Thus a Prussian blue dyed over a safflower red, or *vice versâ*, will produce any of these tints by varying the depth of the red and blue according to the shade required; but the same shades can be produced direct by logwood and an aluminous or tin mordant; the stuff being steeped in sumach liquor previous to applying the tin mordant produces the reddish or purple tint when such is required.

3. Red with black; brown, chocolate, maroon, &c. These tints are produced by various processes. To dye a deep orange by annotto liquor, and then form over it a black by sumach and sulphate of iron, gives a brown; or dye the stuff first a rich yellow by quercitron and a tin mordant, and then over the yellow produce a purple by passing it through logwood; chocolates are thus produced. A little Brazil wood with the logwood gives more of the red element. When maroon is required, the red is made to prevail, and so by a judicious mixture, these various tints are produced. Brown, especially upon cotton fibre, is more often produced direct by means of catechu. Steep the stuff in a hot solution of catechu, in which the gummy principle has been destroyed by the addition of a salt of copper; then pass through a solution of bichromate of potash at boiling heat, when a rich brown is obtained.

4. Yellow with blue; green of a great variety of shades; such as nascent green, gay green, grass green, spring green, laurel green, sea green, celadon green, parrot green, cabbage green, apple green, duck green.

Green is essentially a mixed dye, and produced by dyeing a blue over a yellow or a yellow over a blue. In almost all cases the blue is dyed first, and then the yellow, and according to the depth of each or any of these are the various tints of green produced. With silk and wool, one kind of green dye may be produced simultaneously by putting sulphate of indigo into the yellow dye bath, and then working the previously prepared or mordanted stuff in this. With cotton, an arsenite of copper (Scheele's green) may be produced by working the stuff in a solution of arsenite of potash or soda, and then in sulphate of copper, which produces a peculiar tint of green.

5. Mixtures of colours, three and three, and four and four, produce an indefinite diversity of tints: thus, red, yellow, and blue form brown olives and greenish greys; in which the blue dye ought always to be first given, lest the indigo vat should be soiled by other colours, or the other colours spoiled by the alkaline action of the vat. Red, yellow, and grey (which is a gradation of black) give the dead-leaf tint, as well as dark orange, snuff colour, &c. Red, blue and grey give a vast variety of shades; as lead grey, slate grey, wood-pigeon grey, and other colours too numerous to specify. See BROWN DYE.

Care must be taken, however, in mixing these colours, to study the depth of the tint required; as, for instance, were we wishing to dye a slate grey, and to proceed first by dyeing a blue, then a red, with a little of the grey, we would produce, instead of a slate gray, a purple or peach. The arrangement referred to, applies only to the

elements of the colours that enter into the composition of the various tints, so that a slate grey is a blue with a small portion of red, and a still smaller portion of the black element, that produces the grey tint. Thus, dye the stuff first a deep sky blue by the vat, then by passing through a solution of sumach, with a small quantity of logwood, Brazil wood, copperas, and alum, grey will be produced. The Brazil wood gives the red tint, sumach and copperas the black tint, the logwood assisting in this, and with the aid of the alum throwing in the puce or dove neck hue; and thus by the variation of these hues by such arrangements, any of the grey tints can be produced. See CALICO PRINTING.

DYER'S ALKANET, *Alkanna tinctoria.* See ALKANET.

DYER'S MADDER, *Rubia tinctorium.* See MADDER.

DYER'S OAK, *Quercus infectoria.* See GALLS and OAK.

DYER'S ORCHELLA WEED, *Roccella tinctoria.* See ARCHIL, ORCHELLA.

DYER'S SAFFLOWER, or Bastard saffron. The *Carthamus tinctorius.* The flowers are of a deep orange colour, but they are used for dyeing various shades of red. The flowers of the carthamus are employed in Spain for colouring dishes and confectionery. See SAFFLOWER.

DYER'S WOODROOF. *Asperula tinctoria.* The roots of this plant are used in some parts of Europe, particularly Dalmatia, instead of madder, for dyeing wool and cloth of a reddish colour; but in bulk the crop obtained is inferior to that of the madder. — *Lawson.*

E.

EARTHS. (*Terres*, Fr.; *Erden*, Germ.) It has been demonstrated that the substances called Earths, and which, prior to the electro-chemical career of Davy, were deemed to be elementary bodies, are all compounds of certain metallic bases and oxygen. Five of the earths, when pure, possess decided alkaline properties, being more or less soluble in water, having (at least three of them) an acrid alkaline taste, changing the purple infusion of red cabbage to green, most readily saturating the acids, and affording thereby neutro-saline crystals; these are *baryta*, *strontia*, *lime* (*calcia*), *magnesia*, and *lithia*. The earths proper are *alumina*, *glucina*, *yttria*, *zirconia*, and *thorina*; these do not change the colour of infusion of cabbage or tincture of litmus, do not readily neutralise acidity, and are quite insoluble in water.

EARTHY COBALT. See WAD. A manganese ore, in which the oxide of cobalt sometimes amounts to thirty-three per cent. — *Dana.*

EARTHY MANGANESE. See WAD and MANGANESE.

EAST INDIA BLACK WOOD. The Sit Sâl of the natives of India. The *Dalbergia latifolia.* It is a wood of a greenish black colour, with light coloured veins. It takes a fine polish, and is very heavy.

EAU DE COLOGNE. See PERFUMERY.

EAU DE LUCE. See PERFUMERY.

EBONY. Of this black wood three kinds are imported:—

The Mauritius Ebony, which is the blackest and finest grain.

The East Indian Ebony, which is not of so good a colour.

The African Ebony, which is porous and bad in point of colour.

The ebony of the Mauritius is yielded by the *Diospyrus Ebenus.* Colonel Lloyd says, this ebony when first cut is beautifully sound, but that it splits like all other woods from neglectful exposure to the sun. The workmen who use it immerse it in water as soon as it is felled for from six to eighteen months; it is then taken out, and the two ends are secured from splitting by iron rings and wedges. Colonel Lloyd considers that next to the Mauritius, the ebony of Madagascar is the best, and next that of Ceylon.

The Mauritius ebony is imported in round sticks like scaffold poles, about fourteen inches in diameter. The East Indian variety comes to us in logs as large as twenty-eight inches diameter, and also in planks. The Cape of Good Hope ebony arrives in England in billets, and is called billet wood, about from three to six feet long, and two to four inches thick.

The uses of ebony are well known.

White Ebony comes from the Isle of France, and is much like box wood. See GREEN EBONY.

EBULLITION. (Eng. and Fr.; *Kochen*, Germ.) *Boiling.* When the bottom of an open vessel containing water is exposed to heat, the lowest stratum of fluid immediately expands, becomes therefore specifically lighter, and rises through the colder and heavier particles. The heat is in this way diffused through the whole liquid

mass, not by simple communication of that power from particle to particle as in solids, —called the *conduction* of caloric,—but by a translation of the several particles from the bottom to the top, and the top to the bottom, in regular succession. This is denominated the *carrying* powers of fluids, being common to both liquid and gaseous bodies. These internal movements may be rendered very conspicuous and instructive, by mingling a little powdered amber with water, contained in a tall glass cylinder, standing upon a sand-bath. That this molecular translation or locomotion is almost the sole mode in which fluids get heated, may be demonstrated by placing the middle of a pretty long glass tube, nearly filled with water, obliquely over an argand flame. The upper half of the liquid will soon boil, but the portion under the middle will continue cool, so that a lump of ice may remain for a considerable time at the bottom. When the heat is rapidly applied, the liquid is thrown into agitation, in consequence of elastic vapour being suddenly generated at the bottom of the vessel, and being as suddenly condensed at a little distance above it by the surrounding cold column. These alternate expansions and contractions of volume become more manifest as the liquid becomes hotter, and constitute the *simmering*, vibratory sound which is the prelude of ebullition. The whole mass being now heated to a pitch compatible with its permanent elasticity, becomes turbulent and explosive under the continued influence of fire, and emitting more or less copious volumes of vapour, is said to boil. The further elevation of temperature, by the influence of caloric, becomes impossible in these circumstances with almost all liquids, because the vapour carries off from them as much heat in a latent state as they are capable of receiving from the fire.

The temperature at which liquids boil in the open air varies with the degree of atmospheric pressure, being higher as that is increased, and lower as it is diminished. Hence boiling water is colder by some degrees in an elevated situation, with a depressed barometer, than at the bottom of a coal-pit in fine weather, or, when the barometer is elevated. A high column of liquid also, by resisting the discharge of the steam, raises the boiling point. As we ascend from the sea level, the boiling point becomes lower, the following table illustrates this.

	Yards high.	Inches of pressure.	Boiling point.
Farm of Antisana	4488	17·87	187·34
Quito	3170	20·74	194·18
Mexico	2490	22·52	198·14
St. Gothard	2302	23·02	199·22
Briançon	1423	25·39	203·9
Monte Dore	1136	26·26	205·7
Madrid	665	27·72	208·04
Moscow	328	28·82	210·2
Lyons	177	29·33	210·92
Paris	71	29·69	211·46

Nichol.

In *vacuo*, all liquids boil at a temperature about 124° F. lower than under the average atmospheric pressure. For a table of elasticities, see VAPOUR. Gay-Lussac has shown that liquids are converted into vapours more readily, or with less turbulence, when they are in contact with angular or irregular, than with smooth surfaces; that they therefore boil at a heat 2° F. lower in metallic than in glass vessels, probably owing to the greater polish of the latter. For example, if into water about to boil in a glass matrass, iron filings, ground glass, or any other insoluble powder be thrown, such a brisk ebullition will be instantly determined, as will sometimes throw the water out of the vessel; the temperature at the same time sinking two degrees F.

The following table exhibits the boiling heat, by Fahrenheit's scale, of the most important liquids:—

Ether		Graham	96°
Ether, specific gravity 0·7365 at 48°			100
Carburet of sulphur			113
do.		Graham	118
Alcohol, sp. grav. 0·813		Ure	173·5
Nitric acid, do. 1·500		Dalton	210
do. do. 1·42		Graham	248
Water			212
Saturated solution of Glauber salt		Biot	213½
do. do. Acetate of lead		do.	215½
do do. Sea salt		do.	224½
do do. Muriate of lime		Ure	285
do. do. do. 1 + water 2		do.	230

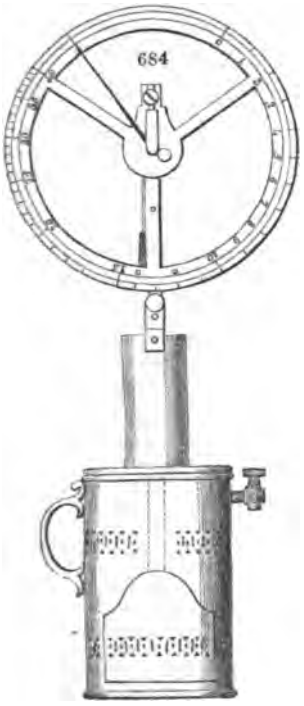
Saturated solution of muriate of lime, 35·5 + water, 64·5		Ure	235°
Ammonia		Graham	140
Crystallised chloride of calcium		do.	302
Saturated solution of muriate of lime, 40·5 + water, 59·5		Ure	240
Muriatic acid, sp. grav.	1·094	Dalton	232
do. do.	1·127	do.	222
Nitric acid, do.	1·420	do.	248
do. do.	1·30	do.	236
Rectified petroleum		Ure	306
Oil of turpentine		do.	316
Sulphuric acid, sp. grav.	1·848	Dalton	600
do. do.	1·810	do.	473
do. do.	1·780	do.	435
do. do.	1·700	do.	374
do. do.	1·650	do.	350
do. do.	1·520	do.	290
do. do.	1·408	do.	260
do. do.	1·300	do.	240
Phosphorus		do.	554
Sulphur		do.	570
Linseed oil		do.	640
Whale oil		Graham	630
Mercury		Dulong	662
do.		Crighton	656
Saturated solution of acetate soda, containing	60 per cent.	Griffiths	256
do. Nitrate of soda,	60	do.	246
do. Rochelle salt,	90	do.	240
do. Nitre,	74	do.	238
do. Muriate of ammonia,	50	do.	236
do. Tartrate of potash,	68	do.	234
do. Muriate of soda,	30	do.	224
do. Sulphate of magnesia,	57·5	do.	222
do. Borax,	52·5	do.	222
do. Phosphate of soda,	?	do.	222
do. Carbonate of soda,	?	do.	220
do. Alum,	52	do.	220
do. Chlorate of potash,	40	do.	218
do. Sulphate of copper,	45	do.	216

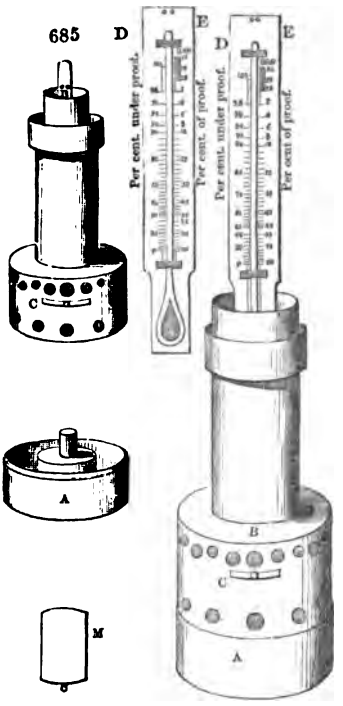
EBULLITION ALCOHOLMETER. That the boiling temperature of water is increased by holding neutro-saline and saccharine substances in solution has been long known, and has been the subject of many experiments, made partly with the view of ascertaining from that temperature the proportion of the salt or sugar, and partly with the view of obtaining a practical liquid bath. But it seems to have been reserved for the Abbé Brossard-Vidal, of Toulon, to have discovered that the boiling temperature of alcoholic liquors is, in most cases, proportional to the quantity of alcohol, irrespectively of the quantity of neutro-saline or saccharine matter dissolved in them. When, however, such a quantity of dry carbonate of potash, or sugar, is added to a spirituous liquor as to abstract or fix in the solid state a portion of the water present, then the boiling temperature of that mixture will be lowered in proportion to the concentration of the alcohol, instead of being raised, as would be the case with water so mixed. But, generally speaking, it may be assumed as a fact, that the boiling point of an alcoholic liquor is not altered by a moderate addition of saline, saccharine, or extractive matter. On this principle, M. Brossard-Vidal constructed the instrument represented in *fig.* 684, for determining by that temperature the proportion of alcohol present. His chief object was to furnish the revenue boards of France with a means of estimating directly the proportion of alcohol in wines, so as to detect the too common practice of introducing brandy into their cities and towns under the mask of wine, and thereby committing a fraud upon the *octroi*; as the duty on spirits is much higher than on wines.

The above instrument consists of a spirit-lamp, surmounted by a small boiler, into which a large cylindric glass bulb is plunged, having an upright stem of such calibre that the quicksilver contained may, by its expansion and ascent when heated, raise before it a little glass float in the stem, which is connected by a thread with a similar glass bead, that hangs in the air. The thread passes round a pulley, which turning with the motion of the beads causes the index to move along the graduated circular scale. The numbers on this scale represent per centages of absolute alcohol, so that

the number opposite to which the index stops, when the liquor in the cylinder over the lamp boils briskly, denotes the per centage of alcohol in it.

Dr. Ure introduced another form of instrument (*fig.* 685). It is thus described by the inventor:—





It consists, 1, of a flat spirit-lamp A, surrounded by a saucer for containing cold water to keep the lamp cool, should many experiments require to be made in succession; 2, of the boiler B, which fits by its bottom cage C, upon the case of the lamp. At the point C, is seen the edge of the damper-plate for modifying the flame of the lamp, or extinguishing it when the experiment is completed. D is the thermometer, made with a very minute bore, in the manner of the Rev. Mr. Wollaston's instrument for measuring the height of a mountain by the boiling point of water on its summit. The bottom of the scale in the ebullition thermometer, is marked P for proof on the left side, and 100 (of proof spirit) on the right side. It corresponds to 178·6 Fahr. very nearly, or the boiling point of alcohol of 0·920 specific gravity. The following table gives the boiling points corresponding to the indicated densities: —

Temp. Fahr.	Specific gravity.		Temp. Fahr.	Specific gravity.	
178·6	0·9200	P.	185·6	0·9665	50 U. P.
179·75	0·9321	10 U. P.	189·0	0·9729	60 „
180·4	0·9420	20 „	191·8	0·9786	70 „
181·0	0·9516	30 „	196·4	0·9850	80 „
183·4	0·960	40 „	202·0	0·992	90 „

The above table is the mean of a great many experiments. When alcohol is stronger than 0·92, or the excise proof, its boiling point varies too little with its progressive increase of strength to render that test applicable in practice. In fact, even for proof spirits, or spirits approaching in strength to proof, a more exact indication may be obtained by diluting them with their own bulk of water, before ascertaining their strength and then doubling it.

The boiling point of any alcoholic liquor is apt to rise if the heat be long continued, and thereby to lead into error in using this instrument. This source of fallacy may be, in a great measure avoided by adding to the liquor in the little boiler about a teaspoonful (thirty-five grains) of common culinary salt, which has the curious effect of arresting the mercury in the thermometer at the true boiling point of the spirit,

wine, or beer, to enable a correct reading to be had. The small measure marked M holds the requisite quantity of salt.

The thermometer is at first adjusted to an atmospheric pressure of 29·5 inches. When that pressure is higher or lower, both water and alcohol boil at a somewhat higher or lower temperature. In order to correct the error which would hence arise in the indications of this instrument under different states of the weather, a barometrical equation is attached, by means of the subsidiary scale E, to the thermometer D.

Having stated the principles and the construction of the ebullition of the alcoholmeter, I shall now describe the mode of its application.

First.—Light the spirit lamp A.

Second.—Charge the boiling vessel B, with the liquid to be tested (to within an inch of the top), introducing at the same time a paper of the powder; then place the vessel B (the damper plate being withdrawn) on to the lamp A.

Third.—Fix the thermometer D on the stem attached to B, with its bulb immersed in the liquid. The process will then be in operation.

The barometrical scale indicated on the thermometer is opposite the mean boiling point of water. Prior to commencing operations for the day, charge the boiler B with water only, and fix the instrument as directed; when the water boils freely, the mercury will become stationary in the stem of the thermometer, opposite to the true barometrical indication at the time. Should the mercury stand at the line 29·5 this will be the height of the barometer, and no correction will be required; but should it stand at any other line, above or below, then the various boiling points will bear reference to that boiling point.

In testing spirituous or fermented liquors of any kind, when the mercury begins to rise out of the bulb of the thermometer into the stem, push the damper-plate halfway in its groove to moderate the heat of the flame. When the liquor boils freely the mercury will become stationary in the stem; and opposite to its indication, on the left, the underproof percentage of spirit may be read off at once, if the barometer stand that day at 29·5 inches; while on the right hand scale, the percentage of proof spirit is shown; being the difference of the former number from 100. The damper-plate is to be immediately pushed home to extinguish the flame.

The alcoholmeter will by itself only indicate the percentage of alcohol contained in any wine, but by the aid of the hydrometer, the proportionate quantity of saccharum in all wines may be readily and easily determined. The hydrometer will show the specific gravity of the liquid upon reference to table No. 1, annexed. In testing a sample of wine, first take the specific gravity, and suppose it to be 989, then charge the boiler of the alcoholmeter with the wine, as directed, and at the boiling point it indicates the presence of alcohol at 69·6 per cent.$^{u.p.}$, whose specific gravity will be found to be 979; deduct that gravity from the gravity of the bulk, or 989, and 10 will remain, which 10 degrees of gravity, upon reference to the wine table, will be found to represent 25 lbs. of saccharine or extractive matter in every 100 gallons, combined with 30$\frac{1}{10}$th gallons of proof spirit.

Sikes's hydrometer will only show the sp. gr. of liquids lighter than water (or 1000), and for wines in general use, the gravities being lighter than that article, will answer every purpose; but there are wines whose gravities are heavier than water, such as mountain, tent, rich Malagas, lachrymæ Christi, &c., to embrace which additional weights to the hydrometer will be required, as for cordialised spirits, &c. In testing a sample of rich mountain, its sp. gr. was found to be 1039, or 39 degrees heavier than water; that wine at the boiling point indicated the alcohol 72·5 per cent.$^{u.p.}$; but 980 sp. gr. deducted from 1039 leaves 39 degrees of sp. gr.; against 59 of the wine tables will be found 147–5 or 147$\frac{1}{2}$ lbs. of saccharine or extractive matter, combined with 27$\frac{1}{2}$ gallons of proof spirit to every 100 gallons.

Should the barometer for the day show any other indication above or below the standard of 29·5, the thermometer scale will then only show the apparent strength, and reference must be had to the small ivory indicator, E, it being the counterpart of the barometrical scale of the thermometer; thus, should the barometer indicate 30, place 30 of the indicator against the boiling point of the liquid, and opposite the line of 29·5 will be found the true strength.

Example 1.—Barometer at 30.—Suppose the mercury to stop at the boiling-point 72$^{u.p.}$, place 30 of the indicator against 72 on the thermometer, and the line of 29·5 will cut 69·6$^{u.p.}$, the true strength.

Example 2.—Barometer at 29.—Suppose the mercury to stop at the same point, 72.$^{u.p.}$, place 29 of the indicator against 72 on the thermometer, and the line of 29·5 will cut 74·3$^{u.p.}$, the true strength.

For malted liquors.—To all brewers and dealers in fermented liquors, this principle, by its application, will supply a great desideratum, as it will not only show the alcohol created in the wort by the attenuation, as well as the original weight of the wort prior

No. 1.

TABLE OF SPECIFIC GRAVITIES, by Sikes's Hydrometer, adapted to Field's Patent Alcoholmeter for Cordialized Spirits.

TEMPERATURE 60°. SPECIFIC GRAVITY OF WATER 1000°.

60		70		80		90		100		110		120		130		140		150		160		170		180	
Wt.	S. G.	Wt.	S. G.	Wt.	S. G.	Wt.	S. G.	Wt.	S. G.	Wt.	S. G.	Wt.	S. G.	Wt.	S. G.	Wt.	S. G.	Wt.	S. G.	Wt.	S. G.	Wt.	S. G.	Wt.	S. G.
60	922	70	942	80	961	90	981	100	1000	110	1020	120	1041	130	1063	140	1085	150	1107	160	1129	170	1152	180	1175
1	924	1	943	1	963	1	983	1	1002	1	1022	1	1044	1	1065	1	1087	1	1109	1	1131	1	1155	1	1178
2	926	2	945	2	965	2	985	2	1004	2	1024	2	1046	2	1067	2	1089	2	1111	2	1134	2	1157	2	1180
3	928	3	947	3	967	3	987	3	1006	3	1026	3	1048	3	1069	3	1091	3	1113	3	1136	3	1159	3	1182
4	930	4	949	4	969	4	989	4	1008	4	1029	4	1050	4	1071	4	1093	4	1116	4	1139	4	1162	4	1185
5	932	5	951	5	971	5	991	5	1010	5	1031	5	1052	5	1074	5	1096	5	1118	5	1141	5	1164	5	1187
6	934	6	953	6	973	6	993	6	1012	6	1033	6	1054	6	1076	6	1098	6	1120	6	1143	6	1166	6	1189
7	936	7	955	7	975	7	995	7	1014	7	1035	7	1056	7	1078	7	1100	7	1123	7	1145	7	1168	7	1191
8	938	8	957	8	977	8	997	8	1016	8	1037	8	1058	8	1080	8	1102	8	1125	8	1148	8	1171	8	1194
9	940	9	959	9	979	9	999	9	1018	9	1039	9	1061	9	1082	9	1104	9	1127	9	1150	9	1173	9	1196
10	942	10	961	10	981	10	1000	10	1020	10	1041	10	1063	10	1085	10	1107	10	1129	10	1152	10	1175	10	1199

The foregoing Table, which shows the Specific Gravity on the bulk of the mixture, bear reference to the Table (No. 2.) of the Alcoholmeter following.

No. 2.

TABLE, showing the lbs. of Sugar per Gallon in Cordialized Spirits, with Per Centages to be added to the indicated Strength, per the Alcoholmeter.

Difference of Gravity. Lbs. of Sugar per Gallon.		10 4 oz. or 25 to 100	15 6 oz. 37½ to 100.	20 8 oz. 50 to 100.	25 10 oz. 62½ to 100.	30 12 oz. 75 to 100.	35 14 oz. 87½ to 100.	40 1·0	45 oz. 1·2	50 oz. 1·4	Difference of Gravity. Lbs. of Sugar per Gallon.	
Sp. Grav. of Spirit.	Per Cent. of Spirit.										Per Cent. of Spirit.	Sp. Grav. of Spirit.
920	Pf.	1·6	2·5	3·4	4·4	5·3	6·2	7·1	8·1	9·0	Pf.	920
923	2·5	1·6	2·5	3·3	4·3	5·2	6·1	6·9	7·8	8·8	2·5	923
926	5·	1·5	2·4	3·2	4·2	5·0	5·9	6·8	7·7	8·6	5·	926
929	7·5	1·5	2·3	3·2	4·1	4·9	5·8	6·6	7·5	8·4	7·5	929
932	10·	1·4	2·2	3·1	4·0	4·8	5·7	6·5	7·4	8·2	10·	932
935	12·5	1·4	2·2	3·1	3·9	4·7	5·5	6·3	7·2	8·0	12·5	935
938	15·	1·4	2·1	3·0	3·8	4·6	5·4	6·2	7·0	7·8	15·	938
940	17·5	1·3	2·1	2·9	3·7	4·5	5·3	6·0	6·8	7·6	17·5	940
943	20·	1·3	2·0	2·8	3·6	4·4	5·2	5·9	6·7	7·5	20·	943
945	22·5	1·3	2·0	2·7	3·5	4·3	5·0	5·7	6·5	7·3	22·5	945
948	25·	1·2	1·9	2·6	3·4	4·1	4·8	5·5	6·3	7·0	25·	948
950	27·5	1·2	1·9	2·5	3·3	4·0	4·7	5·3	6·1	6·8	27·5	950
952	30·	1·1	1·8	2·4	3·1	3·8	4·5	5·1	5·8	6·5	30·	952
954	32·5	1·1	1·7	2·3	3·0	3·6	4·3	4·8	5·5	6·2	32·5	954
956	35·	1·0	1·6	2·2	2·9	3·5	4·1	4·6	5·3	6·0	35·	956
958	37·5	1·0	1·6	2·1	2·8	3·4	3·9	4·4	5·1	5·8	37·5	958
960	40·	·9	1·5	2·0	2·7	3·2	3·8	4·3	4·9	5·5	40·	960
962	42·5	·9	1·5	2·0	2·6	3·1	3·6	4·1	4·7	5·3	42·5	962
964	45·	·9	1·4	1·9	2·5	3·0	3·5	4·0	4·6	5·1	45·	964
965	47·5	·8	1·4	1·9	2·4	2·9	3·4	3·9	4·4	4·9	47·5	965
967	50·	·8	1·3	1·8	2·3	2·8	3·3	3·8	4·3	4·8	50·	967
969	52·5	·7	1·2	1·7	2·2	2·6	3·1	3·6	4·1	4·5	52·5	969
970	55·	·7	1·2	1·6	2·0	2·4	2·9	3·4	3·8	4·2	55·	970
972	57·5	·6	1·1	1·5	1·9	2·2	2·7	3·1	3·5	3·9	57·5	972
973	60·	·6	1·0	1·4	1·8	2·1	2·5	2·9	3·3	3·6	60·	973
974	62·5	·6	1·0	1·3	1·7	2·0	2·4	2·7	3·1	3·4	62·5	974
976	65·	·5	·9	1·2	1·5	1·8	2·2	2·5	2·8	3·1	65·	976
977	67·5	·5	·8	1·1	1·4	1·7	2·0	2·3	2·6	2·9	67·5	977
979	70·	·4	·7	1·0	1·3	1·5	1·8	2·1	2·4	2·6	70·	979
980	72·5	·4	·7	.9	1·1	1·3	1·6	1·9	2·1	2·3	72·5	980
982	75·	·3	·6	·8	1·0	1·2	1·4	1·6	1·8	2·0	75·	982
983	77·5	·3	·5	·7	·9	1·0	1·2	1·4	1·6	1·8	77·5	983
984	80·	·2	·4	·6	·8	·9	1·0	1·2	1·4	1·6	80·	984
986	82 5	·2	·3	·5	·7	·8	·9	1·0	1·2	1·4	82·5	986
988	85·	·2	·2	·4	·6	·7	·8	·9	1·0	1·2	85·	988
990	87·5	·1	·2	·3	·5	·6	·7	·8	·9	1·0	87·5	990
992	90·	·1	·1	·2	·4	·5	·6	·7	·8	·9	90·	992
994	92·5	- -	·1	·2	·3	·4	·5	·6	·7	·8	92·5	994
996	95·	- -	- -	·1	·2	·3	·4	5	·6	·7	95·	996
998	97·5	- -	- -	- -	·1	·2	·3	·4	·5	·6	97·5	998

to fermentation, but it will indicate the value of malt liquors in relation to their component parts. It will likewise be a ready means of testing the relative value of worts from sugar compared with grain, as well as being a guide to the condition of stock beers and ales.

To ascertain the strength of malt liquors and their respective values, the instrument has been supplied with a glass saccharometer, testing-glass, and slide-rule. Commence by charging the testing-glass with the liquid, then insert the saccharometer, to ascertain its present gravity or density per barrel, and at whatever number it floats, that will indicate the number of pounds per barrel heavier than water.

Example 1.—Suppose the saccharometer to float at the figure 8, that would indicate 8 lbs. per barrel; then submit the liquid to the boiling test, with the salt as before directed, and suppose it should show (the barometrical differences being accounted for) 90°-P., that would be equivalent to 10 per cent. of proof alcohol. Refer to the slide rule,

and place A on the slide against 10 on the upper line of figures, and facing B on the lower line will be 18, thus showing that 18 lbs. per barrel have been decomposed to constitute that percentage of spirit; then, by adding the 18 lbs. to the present 8 lbs. per barrel, the result will be 26 lbs., the original weight of the wort after leaving the copper.

Example 2.—The saccharometer marks 10 lbs. per barrel, and at the boiling point it indicates 88°·P· equivalent to 12 gallons of proof spirit per cent.; place A against 12, and opposite B will be 21½ lbs. per barrel, when, by adding that to the 10 lbs. present, 31½ lbs. will be the result.

To ascertain the relative value.—Suppose the price of the 26 lbs. of beer to be 36*s.* per barrel, and the 31½ lbs. beer to be 40*s.* per barrel, to ascertain which beer will be the cheapest place 26 on the opposite side of the rule against 36, and opposite 31½ lbs. will be 43*s.* 7*d.*, showing that the latter beer is the cheapest by 3*s.* 7*d.* per barrel.

By taking an account of the malt liquors by this instrument prior to stocking, it may be ascertained at any time whether any alteration has taken place in their condition, either by an increase of spirit by after fermentation and consequent loss of saccharum, or whether, by an apparent loss of both, acetous fermentation has not been going on towards the ultimate loss of the whole.

This instrument will likewise truly indicate the quantity of spirit per cent. created in distillers' worts, whether in process of fermentation or ready for the still; the only difference will be in the allowances on the slide-rule.

N.B.—The saccharometers applicable to the foregoing rules for beer, ales, &c., have been adjusted at the temperature of 60° Fahrenheit, and will be found correct for general purposes; but where extreme minuteness is required, the variation of temperature must be taken into account; therefore for every 10 degrees of temperature above 60, $\frac{1}{10}$ths of a pound must be added to the gross amount found by the slide-rule; on the contrary, for every 10 degrees below 60, $\frac{1}{10}$ths of a pound must be deducted.

For cordialised Spirits.—The operation in this instance is somewhat different from that of beers, which have the alcohol created in the original worts; whereas, in cordialised spirits, gins, &c., the alcohol is the original, and the saccharine matter, or sugar, is an addendum.

If 100 gallons of spirits are required at a given strength, say 50 per cent. under proof, 50 gallons of proof spirit, with the addition of fifty gallons of water, would effect that object, and upon testing it by the alcoholmeter, it would be found as correct as by the hydrometer. But in cordialising spirits it is different, for to the 50 gallons of proof spirit 50 gallons of sugar and water would be added, thereby rendering the hydrometer useless, except for taking the specific gravity of the bulk, and according to the quantity of sugar present, so a relative quantity of water must have been displaced; and as the sugar has no reducing properties, the alcoholmeter will only show the strength of the cordial in relation to the water contained in it, as the principle indicates, irrespectively of saccharine or extractive matter present.

Suppose, in making 100 gallons of cordial at 50°·P·, 3 lbs. of sugar are put to the gallon, or 300 lbs. to the 100 gallons, that 300 lbs., displacing 18$\frac{67}{100}$th gallons of water, only 31$\frac{33}{100}$th gallons of water instead of 50 have been applied; the sugar, without reducing properties, making up the bulk of 100 gallons, which is meant to represent 50 per cent °·P·.

The alcoholmeter will only show at the full point of ebullition the alcoholic strength in relation to the water in the 100 gallons of the mixture, or 35 per cent.°·P·, leaving 15 per cent. to be accounted for on the bulk.

As the quantity of sugar present must be determined before that percentage can be arrived at, a double object will be effected by so doing, namely eliciting in all instances the quantity of sugar present, as well as the percentage of spirit to be accounted for.

Example 1.—In taking the sp. gr. of a cordial, suppose it to be found 1076, then submit the liquid to the boiling point, and having ascertained the percentage of alcohol, and it proves to be 35°·P·, the sp. gr. of alcohol at that strength will be found to be 956; deduct 956 from the sp. gr. of the bulk, or 1076, and 120 will remain; refer that to its amount on the head line of the table No 2, namely, 120, under which will be found 3, representing 3 lbs. of sugar to the gallon; and by running the eye down its column to opposite the alcoholic strength indicated (35°·P·) will be found 14·9, which represents the percentage of water displaced by the sugar, and which amount of 14·9, added to the 35 per cent. ascertained, makes the total upon the bulk 49·9 per cent.°·P·, with 3 lbs. of sugar to the gallon.

For Gins, &c.—Example 2. In taking the sp. gr., suppose it to be found 957; then submit to the boiling point, and it proves to be 14°·P·, whose sp. gr. is 937, which deducted from 957, leaves sp. gr. 20; on the head-line of table No. 2, under 20, will be found 8 oz., or ½ lb. of sugar to the gallon, and on running the eye down to opposite

$14^{n.p.}$, will be found 3·0, which added to the 14, makes the total on the bulk 17 per cent.$^{n.p.}$, with 50 lbs. of sugar to the 100 gallons.

To chemists for their tinctures, &c., this instrument will be found essentially useful.

N.B.—Care must be taken that the mercury is entirely in the bulb of the thermometer before it is fixed on the stem for operation, and in all cases (except for water) the salt must be used.

EDGE TOOLS; more properly *cutting tools*, of which the chisel may be regarded as the type. Holtzapffel, whose book on *Mechanical Manipulation* is the best to be found in any language, divides cutting tools into three groups,—namely paring tools, scraping tools, and shearing tools.

First. Paring or splitting tools, with thin edges, the angles of which do not exceed sixty degrees; one plane of the edge being nearly coincident with the plane of the work produced (or with the tangent in circular work). These tools remove the fibres principally in the direction of their length, or longitudinally, and they produce large coarse chips, or shavings, by acting like the common wedge applied to mechanical power.

Secondly. Scraping tools, with thick edges, that measure from sixty to one hundred and twenty degrees. The planes of the edges form nearly equal angles with the surface produced, or else the one plane is nearly or quite perpendicular to the face of the work (or becomes as a radius to the circle). These tools remove the fibres in all directions with nearly equal facility, and they produce fine dust-like shavings by acting superficially.

Thirdly. Shearing, or separating tools, with edges of from sixty to ninety degree generally duplex, and then applied on opposite sides of the substances. One plane of each tool, or of the single tool, coincident with the plane produced.

Mr. James Bouydell introduced a process which professes to produce cheap edge tools of excellent quality. We believe the result has not been so satisfactory as the patentee expected. He welds iron and steel together in such a manner that when cut up to form edge tools, the steel will constitute a thin layer to form the cutting edge. He piles a slab or plate of steel upon two or more similar plates of iron, heats in a furnace to a good welding heat, and then passes between grooved or other suitable rollers, to convert it into bars; the steel being in a thin layer either on one of the outer surfaces of the bar, or between two surfaces of iron according to the kind of tool to be made therefrom. The bars thus produced are cut up and manufactured into the shape of the desired articles by forging. If the cutting edge is to extend but a short distance, the steel is applied only near one edge of the pile. The compound bars which have the steel on one side are suitable for chisels and other tools, which have a cutting edge on one side, the iron being ground away when making or sharpening the tool. See CUTLERY; STEEL.

EDULCORATE (*Edulcorer*, Fr.; *Aussüssen*, Germ.) is a word introduced by the alchemists to signify the sweetening, or rather rendering insipid, of acrimonious pulverulent substances, by copious ablutions with water. It means, in modern language, the washing away of all particles soluble in water, by agitation or trituration with this fluid, and subsequent decantation or filtration.

EFFERVESCENCE. (Eng. and Fr.; *Aufbrausen*, Germ.) When gaseous matter is suddenly extricated with a hissing sound during a chemical mixture, or by the application of a chemical solvent to a solid, the phenomenon, from its resemblance to that of simmering or boiling water, is called effervescence. The most familiar example is afforded in the solution of sodaic powders; in which the carbonic acid gas of bicarbonate of soda is extricated by the action of citric or tartaric acid.

EFFLORESCENCE (Eng. and Fr.; *Verwittern*, Germ.) is the spontaneous conversion of a solid, usually crystalline, into a powder, in consequence either of the abstraction of the combined water by the air, as happens to the crystals of sulphate and carbonate of soda; or by the absorption of oxygen and the formation of a saline compound, as in the case of alum schist, and iron pyrites. Saltpetre appears as an efflorescence upon the ground and walls in many situations.

EGGS, HATCHING. See INCUBATION, ARTIFICIAL.

EIDER-DOWN is so called because it is obtained from the *Eider*-duck. These birds build their nests among precipitous rocks, and the female lines them with fine feathers plucked from her breast, among which she lays her five eggs. The natives of the districts frequented by the eider-ducks let themselves down by cords among the dangerous cliffs, to collect the down from the nests. It is used to fill coverlets, pillows, cushions, &c.

ELAINE (called also OLEINE) is the name given by Chevreul to the thin oil, which may be expelled from tallow and other fats, solid or fluid, by pressure either in their natural state or after being saponified, so as to harden the *stearine*. It may be extracted also by digesting the fat in seven or eight times its weight of boiling alcohol, spec. grav.

0·798, till it dissolves the whole. Upon cooling the solution, the stearine falls to the bottom, while the elaine collects in a layer like olive oil, upon the surface of the supernatant solution, reduced by evaporation to one eighth of its bulk. If this elaine be now exposed to a cold temperature, it will deposit its remaining stearine, and become pure. Braconnot obtained it by exposing olive oil to a temperature of about 21° F. in order to cause the congelation of the margarine or stearine (?). The elaine was a greenish yellow liquid; at 14° F. it deposited a little margarine. See OILS and STEARINE.

ELASTIC BANDS. (*Tissus élastiques*, Fr.; *Federharz-zeige*, Germ.) See CAOUTCHOUC and BRAIDING MACHINE.

ELASTICITY. The property which bodies possess of occupying, and tending to occupy, portions of space of determinate volume, or determinate volume and figure, at given pressures and temperatures, and which, in a homogeneous body, manifests itself equally in every part of appreciable magnitude (*Nichol*). The examination of this important subject in KINETICS does not belong to this work. A few remarks, and some explanations, only are necessary.

Elastic Pressure is the force exerted between two bodies at their surface of contact.

Compression is measured by the diminution of volume which the compressible (elastic) body undergoes.

The Modulus or *Coefficient of Elasticity* of a liquid is the ratio of a pressure applied to, and exerted by, the liquid to the accompanying compression, and is therefore the reciprocal of the compressibility. The quantity to which the term *Modulus of Elasticity* was first applied by Dr. Young, is the reciprocal of the extensibility or longitudinal pliability. (See the Edinburgh Transactions, and those of the Royal Society, for the papers of *Barlow*, *Maxwell*, and *Rankine*, and the British Association Reports for those of *Fairbairn*, *Hodgkinson*, &c.)

Various tables, showing the elasticity of metals, glass, &c., have been constructed, and will be found in treatises on mechanics. The following notices of the mechanical properties of woods may prove of considerable interest. The experiments were by Chevandier and Wertheim.

Rods of square section 10 mm in thickness and 2 m in length were prepared, being cut in the direction of the fibres, and the *velocity of sound* in them was determined by the longitudinal vibrations, *their elasticity* from their increase in length, and *their cohesion* by loading them to the point of rupture. Small rods were cut in planes perpendicular to the fibre grain (in directions radial and tangential to the rings of growth) and their elasticity and sound velocity were measured by the lateral vibrations. It was thus again established, that the coefficients of elasticity, as deduced from the vibrations, come out higher than those derived from the elongation.

Names of the woods.	Density.	Sound velocity.			Coefficients of elasticity.			Cohesion.		
		L.	R.	T.	L.	R.	T.	L.	R.	T.
Acacia	0·717	14·9	—	—	1216·9	—	—	7·93	—	—
Fir	0·493	13·96	8·05	4·72	1113·2	94·5	34·1	4·18	0·220	0·297
Hornbeam	0·756	11·80	10·28	7·20	1085·7	208·4	103·4	2·99	1·107	0·618
Birch	0·812	13·32	6·46	9·14	957·2	81·1	155·2	4·30	0·823	1·063
Beech	0·823	10·06	11·06	8·53	980·4	269·7	159·3	3·57	0·885	0·752
Oak	0·808	—	—	—	977·8	—	—	6·49	—	—
Holm-Oak	0·872	11·58	9·24	7·76	921·3	188·7	129·8	5·66	0·582	0·406
Pine	0·559	10·00	8·53	4·78	564·1	97·7	28·6	2·48	0·256	0·196
Sycamore	0·692	13·43	9·02	6·85	1163·8	134·9	80·5	6·16	0·522	0·610
Ash	0·697	14·05	8·39	7·60	1121·4	111·3	102·0	6·78	0·218	0·408
Alder	0·601	13·95	8·25	6·28	1108·1	98·3	59·4	4·54	0·329	0·175
Aspen	0·602	15·30	9·72	5·48	1075·9	107·6	43·4	7·20	0·171	0·414
Maple	0·674	12·36	9·26	6·23	1021·4	157·1	72·7	3·58	0·716	0·371
Poplar	0·477	12·89	8·44	6·32	517·2	73·3	38·9	1·97	0·146	0·214
Elm	—	—	8·56	6·11	—	122·6	63·4	—	0·345	0·366

L refers to rods cut lengthwise with the grain,
R to those cut in a direction radial, and
T to those tangential to the annual rings.

ELATERIUM. A peculiar extract obtained from the juice of the wild cucumber. (*Momordica elaterium*).

ELDER. (*Sambucus nigra*. *Sureau*, Fr.; *Hohlunder*, Germ.) Pith balls for electrical purposes are manufactured from the pith of the elder tree, dried. The wood is employed for inferior turnery work, for weaver's shuttles, netting pins, and shoemakers' pegs. Its elasticity and strength render it peculiarly fitted for these latter purposes.

ELECTIVE AFFINITY. (*Wahlverwandtschaft*, Germ.) See DECOMPOSITION, EQUIVALENTS.

ELECTRIC CLOCKS. The application of electricity as a motive power to clocks, and as a means of transmitting synchronous signals or time, is naturally inti-

mately connected with the attempts (not yet realised in an economic point) to apply it as a motive power to machinery, and with its application, so fully realised (see article ELECTRO-TELEGRAPHY), to telegraphy proper; and it has grown up side by side with the latter. Prof. Wheatstone's attention was directed to it in the very early days of telegraphy. Without entering upon the history of electric clocks, it will suffice to describe two principles on which they have been constructed, and which are best known,—Bain's and Shepherd's. In the former, electricity maintains the pendulum in motion, and the pendulum drives the clock-train; in the latter, the motion of the pendulum is maintained by electricity, but the clock-train is driven by distinct currents, sent to it by means of pendulum contacts.

The bob of Bain's pendulum consists of a coil of wire, wound on a bobbin with a hollow centre. The axis of the bobbin is horizontal. Bar magnets, presenting similar poles, are fixed on each side of the coil, in such a position that, as the pendulum oscillates right and left, the poles on either side may enter the coil of wire. It is one of the laws of electric currents, when circulating in a helix, or spiral, or coil, or even in a single ring, that each face of the coil presents the characters of a magnetic pole, of a south pole if the current circulates in the direction in which the hands of a watch move, of a north pole, if it circulates in the reverse direction. Things are so arranged in Bain's pendulum that a battery current is alternately circulating in and cut off from the coil. When the current is circulating, the coil has the character of a magnet, with a north end and a south end; if the permanent magnets present north poles, the north end of the coil-bob will be repelled from one of the magnets, while its south end will be attracted by the other magnet. This constitutes the impulse or maintaining power in one direction. Now the connections are such that, when the arc of vibration is complete and the pendulum ready for the return vibration, the pendulum rod pushes aside a golden slide, by which the electric circuit had been completed, and the current is cut off; the pendulum is thus able to make its return vibration by mere gravity. It starts to repeat the above operations by mere gravity; but, ere it completes the arc, the rod pushes back the slide, and again completes the electric circuit, and gives rise to a second impulse, and so on. A small amount of magnetic attraction is sufficient to supply the necessary amount of maintaining power. One pair of zinc-copper, buried in the moist earth, has been found ample.

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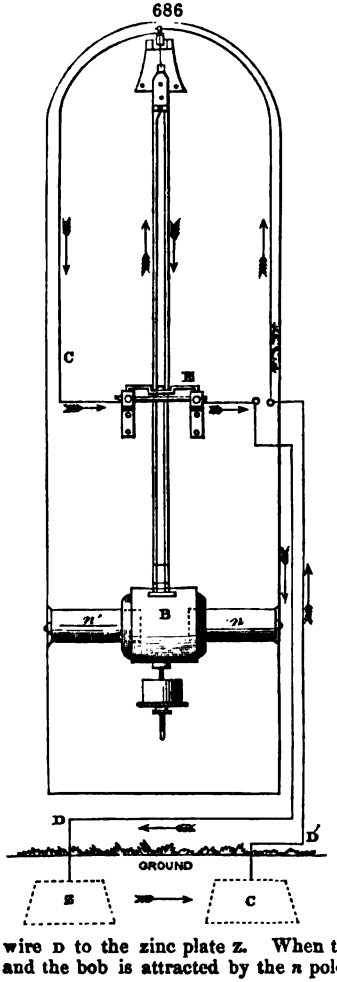

In an ordinary clock, the train is carried by a weight or by a spring, and the time is regulated by the pendulum. In Bain's the time is regulated and the train is driven by the pendulum. The rod hangs within a crutch in the usual way; the crutch carries pallets of a particular kind, acting in a scape-wheel; and from the latter, the motion is transmitted to a train of the usual character; but much lighter. For large clocks, Mr. Bain proposes a modification of the slide, which shall invert the current at each oscillation, so as to have attraction as a maintaining power in both oscillations. The general arrangement of the pendulum is shown in *fig.* 686. B is the pendulum bob, with its coil of wire, the ends of which pass up on either side of the rod. Z and C are the battery plates, with their attached wires D and D'. The arrows show the course of the voltaic current from the plate C by the wire D', thence down the pendulum rod by the right hand wire, through the coil B, up by the wire on left side of rod, then by the wire C, along the slide at E, and by the wire D to the zinc plate Z. When the slide E is in position, the circuit is complete, and the bob is attracted by the *n* pole of one of the magnets, and repelled by the *n*

pole of the other. When the slide is displaced, the attraction ceases, and the pendulum is left to the mere action of gravity.

Shepherd's electric clock has a remontoir escapement. There is no direct connection between the electric force and the pendulum, or between the pendulum and the clock train. The attractive power, derived from the electric current, is simply employed to raise the same small weight to the same height; and the clock-train is carried by the attractive force derived from electric currents, whose circuits are completed by the pendulum touching contact springs. The pendulum is thus protected from the influence of change in the force of the current, or from irregular resistances in the train. *Fig.* 687 is a perspective view of this pendulum, with batteries, s z,

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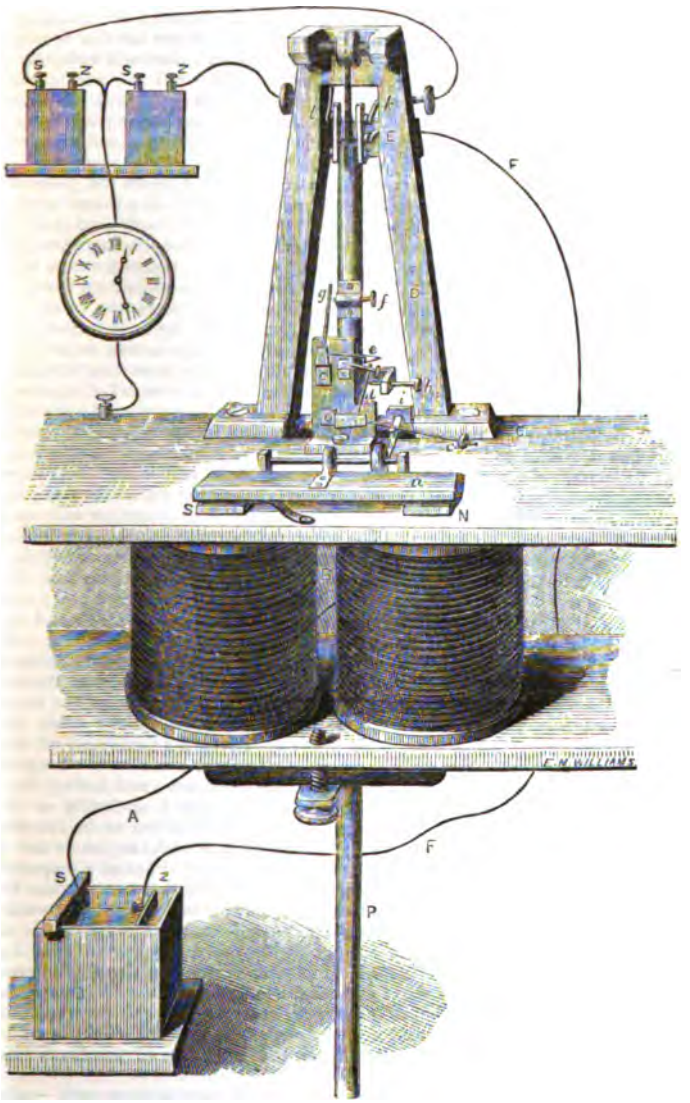

attached, and the clock connections and those of its batteries, *s z s z*, shown. The electricity leaves the pendulum battery by the wire A, and returns to it by the wire F.

There is only one break in this circuit, namely, at E, which is a slender spring faced with platinum, that is in contact with platinum on the pendulum at the extreme of its right vibration, but at no other time. The wire A reaches the pendulum from the battery by the coils B, the plate C, and the frame D; the wire F goes direct from the spring E to the zinc Z. From this arrangement, it happens that every time the contact at E is completed, the iron core, of which the ends N S are visible, contained within the coils B, becomes a magnet, and when the contact at E is broken, the magnetism ceases. The poles N S have, therefore, a power alternately to attract and to release *a*, which is a plate or armature of soft iron, moving on an axis, as shown in the figure, and to which is attached a bar *b*, with a counterpoise *i*. We have said that the office here of the electric force, is merely to raise a weight; the fall of the weight maintains the pendulum in motion. When the armature *a* is attracted, the lever *b* is raised; this raises the wire *c* into a horizontal position, and its other part *d* into a vertical position; the latter is caught and retained by the latch or detent *e*; so that when the magnetic attraction ceases, the counterpoise *i* descends with the lever *b*; and so the armature *a* leaves the electro-magnet N S. But the wire *d* remains vertical, and its other part with the small weight *c* remains horizontal. Now, when the pendulum makes its left hand oscillation, the point of the screw *f* impinges upon the stem *g*, and carries it a little to the left; this raises the detent *e*, and liberates the piece *d c*, which descends into its original position by gravity; the small ball *c* adds to its weight. In descending, the vertical piece *c* strikes against the point of the screw *h*, and gives a small impulse to the pendulum P. The ball *c* is not larger than a pea, and its fall is not an eighth of an inch; but the impact is sufficient to keep the pendulum in motion; and it is constant, being this same body falling through the same space; and is independent of any variation in the battery power, which latter is only concerned in raising the ball. The arc of the pendulum's vibration is regulated by adjusting the small ball to a greater or less distance from the centre. Provision is thus made for maintaining the pendulum in motion, and giving it an impact of constant value. If this arrangement is in connection with a compensating mercurial pendulum, extreme accuracy of time-keeping is attained. The next step is to transfer the seconds, thus secured, to a dial or clock. The same movement of the keeper *a* with its counterpoise *i*, has sometimes been made to impart motion to the seconds wheel of a clock train; but more commonly the clock train is distinct, as shown in the drawing, and is carried by a special electro-magnetic arrangement, in connection with separate batteries, *z c*, *z c*, the contacts of which are, however, under the control of the pendulum. Insulated springs, *k* and *l*, are fixed near the top of the rod; from *k* a wire leads to the silver *s*, of the left hand battery; and from *l* another wire leads to the zinc *z*, of the right hand battery. The other metals of the respective batteries are connected by a wire with an electro-magnet within the clock, the other end of the said electro-magnet being connected with the metal bed and frame of the pendulum. When, therefore, the pendulum oscillates to the right, the circuit is completed at *k*; and the current of the left hand battery circulates from *s* through the wire *k*; and thence through the metal frame and by the wire to the clock, and so to the zinc *z*. When the oscillation is to the left and *l* is in contact, the right hand battery is in action; and the current circulates from *s* through the clock, to the metal frame, and thence to *l* and to the zinc *z* of the battery. In one case, a voltaic current enters the clock by the wire shown below, and leaves it by the upper wire; and, in the other case, it enters by the upper and leaves by the lower wire. There is a double set of electro-magnets within the clock, showing four poles in all; there are also two magnetised steel bars, mounted see-saw fashion, with their poles alternate, and facing the four electro-magnetic poles. When the current enters the clock from below or in one direction, the bars oscillate this way; when it enters from above or in the reverse direction, they oscillate that way. They are both fixed at right angles to and upon the same axis; which axis carries a pair of driving pallets, that act on a scape-wheel, and so the clock-train is driven. It will be seen at a glance, that two or more clocks may be connected in the same circuit, as readily as one; it being merely necessary in such case to modify the battery power, to correspond with the work to be done. For instance, three such clocks have been going for several years at Tonbridge by the same pendulum; several are actuated in like manner at the Royal Observatory, Greenwich. Nor is it necessary that the clocks should be in the same room with the pendulum, or in the same building, or even in the same parish. All the clocks above referred to, are variously distributed; and one of the Observatory clocks is six miles distant from its pendulum, being at the London Bridge Station of the South-Eastern Railway.

In cases where it has not been found convenient to drive the clock train, especially in the case of a public one, the movement of which is heavy, great advantage has been derived for regulating the oscillations of the pendulum of the large clock, by means of electric currents, under the control of a standard pendulum. Mr. Jones

has adopted this method, and it is likely to meet with much favour. The turret clock, under this arrangement, is driven by weights in the usual way, and the time is regulated by a pendulum. The bob of the pendulum is placed under a condition analogous to that of Bain's (*fig.* 686), the permanent magnet, however, being attached to the pendulum, and the electro-magnet fixed facing it. If currents are made to circulate synchronously in the latter, by means of a standard pendulum, the oscillations of the pendulum of the turret-clock are constrained to accord with those of the standard, and a very perfect system of time-keeping is obtained. This is practised at Liverpool; and has just been introduced at Greenwich.

Under the above arrangements the clock is controlled by the standard pendulum second by second, and the two keep time together throughout the day. There are cases in which it is sufficient, and also more convenient, to correct a clock once a day only by means of a telegraph signal transmitted from a standard clock. This is managed in several ways. There is a clock at the Telegraph Office in the Strand; a good regulator, adjusted to gain a second or two during the twenty-four hours, and to stop at 1 P.M. A telegraph signal is sent from the Royal Observatory precisely at one, that drops a time-ball at the Strand office, which, in falling, starts the clock. At Ashford, seventy-three miles from Greenwich, there is an electric clock which has a gaining rate, and which is so constructed that the battery circuit is opened at one o'clock by means of pins and springs attached to the movement, and the clock therefore stops. At 1 P.M., Greenwich mean time, a signal is sent through the Ashford clock from the Royal Observatory, which starts it at once at true time. At the Post office, Lombard Street, there is a clock which, in the course of the twenty-four hours, raises a weight. At noon a telegraph signal is sent from Greenwich, which passes through an electro-magnet; the latter attracts an armature of soft iron and liberates the ball, which falls, and in falling it encounters a crutch, or lever, attached to the second's hand, and thrusts it this way or that, as the case may be; but so as to bring it to sixty seconds on the dial, and thus to set the clock right.

Intermediate between the one method of sending a signal every second to regulate a clock, and the other method of sending it once a day, we have the following arrangement of Bain's for sending it once an hour. *Fig.* 688 shows the arrangement, with part of the dial removed, to show the position of the electro-magnet. The armature is below; it carries a vertical stem, terminating above in a fork. Its ordinary position is shown by the dotted lines. The minute hand (partly removed from the cut) carries a pin on its back surface. When the hand is near to sixty minutes, and an electric current is sent through the magnet, the armature is attracted upwards and the fork takes the position shown by the full lines at the top of the dial, and, in doing so, it encounters the pin and forces the hand into the vertical position, and sets the clock to true time, providing the signal comes from a standard clock, or is sent by hand at true time. A dial of moderate character keeps so near to time, that once or twice a day would be, for all common purposes, often enough to correct it.

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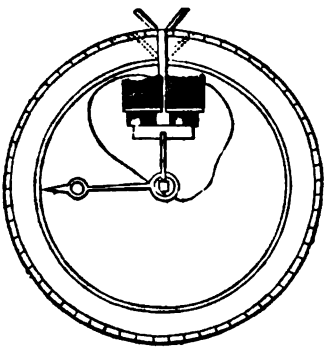

Fig. 689 is an arrangement of Bain's, by which a principal clock, showing seconds, sends electric currents at minute intervals to other clocks, and causes the hand to move minute by minute. A is a voltaic battery; B is the principal clock, which may be an electric clock or not at pleasure; C and H are two out of many subordinate clocks. The seconds hand of the principal clock completes a voltaic circuit twice (for the case of two clocks) during the minute; at the 30 seconds for the clock C, and at the 60 seconds for the clock H. The clock H shows time in leaps from one minute to the next; and the clock C from one half minute to the next half minute. As many more contacts per minute may be provided for the seconds hand of the prime clock as there are subordinate clocks.

Next akin to the time signals above described, and which act automatically upon clocks, either to drive the clock-train or to correct the clock errors, are mere time signals, which are extensively distributed throughout the country by the ordinary telegraph wires, and are looked for at the various telegraph stations, in order to compare the office dials with Greenwich mean time, and to make the necessary correction; they are also re-distributed by hand the moment they appear, through sub-districts branching from junction stations. Large black balls, hoisted in conspicuous stations,

are also dropped daily by electric currents in various places, for the general information of the public, or of the captains of ships.—C. V. W.

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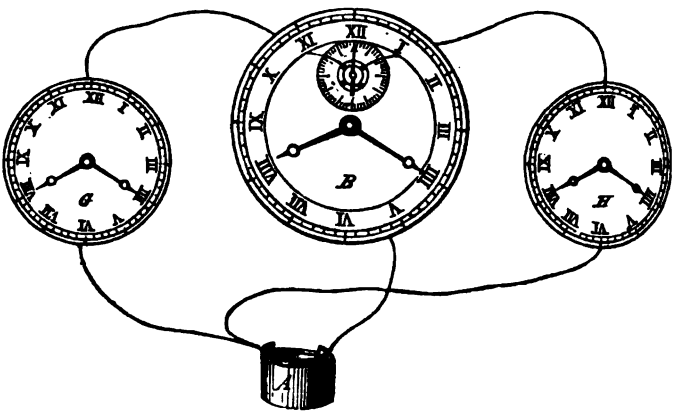

ELECTRICITY *for Blasting in Mines and Quarries.* Professor Hare was the first who entertained this idea, but Mr. Martin Roberts devised the following process. In order not to be called upon to make afresh a new apparatus for each explosion, Mr. Roberts invented cartridges, which may be constructed beforehand. With this view, two copper wires are procured, about a tenth of an inch in diameter, and three yards in length, well covered with silk or cotton tarred, so that their insulation may be very good. They are twisted together (*fig.* 690) for a length of six inches, care being taken to leave their lower extremities free, for a length of about half an inch (separating them about half an inch), from which the insulating envelope is removed, in order to stretch between them a fine iron wire, after having taken the precaution of cleaning them well. The upper extremities of the two copper wires are likewise separated, in order to allow of their being placed respectively in communication with the conductors, that abut upon the poles of a pile. The body of the cartridges is a tin tube, three inches long, and three quarters of an inch in diameter, the solderings of which are very well made, in order that it may be perfectly impermeable to water. A glass tube might equally well be employed, were it not for its fragility, which has caused a tin tube to be preferred. The system of copper wires is introduced into the tube, fixing them by means of a stem that traverses it at such a height that the fine iron wire is situated in the middle of the tin tube, so arranged that the ends of the copper wire do not anywhere touch the sides of the tube (*fig.* 691). The cork is firmly fixed at the upper extremity of the tube with a good cement. Mr. Roberts recommends for this operation, a cement composed of one part of beeswax and two parts of resin; the tube is then filled with powder by its other extremity, which is likewise stopped with a cork, which is cemented in the same manner. *Figure* 692 indicates the manner in which the cartridge is placed in the hole, after having carefully expelled all dust and moisture; care must be taken that the cartridge is situated in the middle of the charge of powder that is introduced into the hole. Above the powder is placed a plug of straw or tow, so as to allow between it and the powder a small space filled with air; and above the plug is poured dry sand, until the hole is filled with it. The two ends of the copper wires that come out of the cartridge are made to communicate with the poles of the pile, by means of conductors of sufficient length, that one may be protected from all dangers arising from the explosion of the mine.

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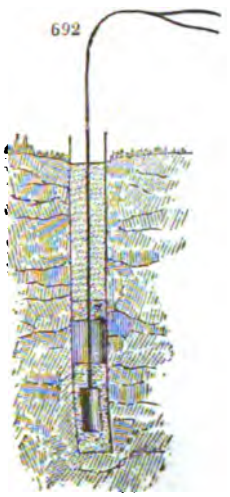
M. Ruhmkorff, and after him, M. Verdu, have successfully tried to substitute the induction spark for the incandescence of a wire, in order to bring about the ignition of the powder. This process, besides the considerable economy that it presents—since instead of from fifteen to twenty Bunsen's pairs, necessary for causing the ignition

of the wire, it requires but a single one for producing the induction spark,—possesses the advantages of being less susceptible of derangement. Only it was necessary to



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contrive a plan to bring about the ignition of the powder; in fact, it happens, that when by the effect of the length of the conductors that abut upon the mine, the circuit presents too great a resistance, the induction spark is able to pass through the powder without inflaming it. M. Ruhmkorff has conceived the happy idea of seeking for a medium, which, more easily inflammable by the spark, may bring about the ignition of the powder in all possible conditions. He found it in Statham's fusees, which are prepared by taking two ends of copper wire covered with ordinary gutta percha; they are twisted (*fig.* 693), and the ends are bent so as to make them enter into an envelope of vulcanised (sulphured) gutta percha, which has been cut and drawn off from a copper wire that had been for a long time covered with it. Upon this envelope a sloping cut *a*, *b*, is formed; and after having maintained the extremities of the copper wires at about the eighth of an inch from each other, their points are covered with fulminate of mercury, in order to render the ignition of the powder more easy. The cut is filled with powder, and the whole is wrapped round with a piece of caoutchouc tube, *c*, *d*, or else it is placed in a cartridge filled with powder.

In the Statham fusees, it is the sulphide (sulphuret) of copper adhering to the wire, produced by the action of the vulcanised gutta percha which is removed from the copper wire that it covered, which by being inflamed under the action of the induction spark brings about an explosion. But it is necessary to take care when the fusee has been prepared, as we have pointed out, to try it in order to regulate the extent of the solution of continuity. It might, in fact, happen that while still belonging to the same envelope of a copper wire, the sheath of a vulcanised gutta percha with which the fusee is furnished, may be more or less impregnated with sulphide of copper; now, if the sulphide of copper is in too great quantity, it becomes too good a conductor, and prevents the spark being produced; if, on the contrary, it is not in a sufficiently large quantity, it does not sufficiently facilitate the discharge.

The first trials on a large scale of the application of the process that we just described, were made with Ruhmkorff's induction apparatus, by the Spanish colonel, Verdu, in the workshops of M. Herkman, manufacturer of gutta percha covered wire, at La Villette, near Paris. Experiments were made successively upon lengths of wire of 400, 600, 1000, 5000, and up to 26,000 metres (of 3·28 feet); and the success was always complete, whether with a circuit composed of two wires, or replacing one of the wires by the earth; two ordinary Bunsen's pairs were sufficient for producing the induction spark with Ruhmkorff's apparatus. Since his first researches with M. Ruhmkorff, M. Verdu has applied himself to fresh researches in Spain; and he was satisfied, by many trials, that of all explosive substances, not any one was nearly so sensitive as fulminate of mercury; only, in order to avoid the danger that arises from the facility of explosion of this compound, he takes the precaution of introducing the extremity of the fusees into a small gutta percha tube, closed at the end. After having filled with powder this species of little box, and having closed it

hermetically, the fusees may be carried about, may be handled, may be allowed to fall, and even squeezed rather hard, without danger. The elastic and, leather-like nature of gutta percha, which has been carefully softened a little at the fire, preserves the fulminate from all chance of accident. We may add, that with a simple Bunsen's pair, and by means of Ruhmkorff's induction apparatus, M. Verdu has succeeded in producing the simultaneous explosion of six small mines, interposed in the same circuit at 320 yards from the apparatus. He has not been beyond this limit; but he has sought for the means of acting indirectly upon a great number of mines, by distributing them into groups of five, and by interposing each of these groups in a special circuit. The fusees of each group are made to communicate by a single wire, one of the extremities of which is buried in the ground, and whose other extremity is near to the apparatus. On touching the induction apparatus successively with each of the free ends that are held in the hand, which requires scarcely a second of time, if there are four wires, that is to say, four groups and consequently twenty mines, twenty explosions are obtained simultaneously at considerable distances. There are no limits either to the distance at which the explosion may take place, or to the number of mines that may thus be made to explode.

ELECTRIC LIGHT. Various attempts have been made, from time to time, to employ electricity as an illuminating power; but hitherto without the desired success. The voltaic battery has been employed as the source of electricity, and in nearly all the arrangements, the beautiful arc of light produced between the poles, from the points of the hardest charcoal, has been the illuminating source. One of the great difficulties in applying this agent arises from the circumstance that there is a transference of the charcoal from one pole to the other, and consequently an alteration in the distance between them. This gives rise to considerable variations in the intensity and colour of the light, and great want of steadiness. Various arrangements, many of them exceedingly ingenious, have been devised to overcome these difficulties.

The most simple of the apparatus which has been devised is that of Mr. Staite, which has been modified by M. Archereau. Two metal columns or stems, to which any desired form can be given, are connected together by three cross pieces, so as to form one solid frame; one of these cross pieces is metallic, it is the one which occupies the upper part of the apparatus; the others must be of wood. These latter serve as supports and points of attachment to a long bobbin placed parallel to the two columns and between them, and which must be made of tolerably thick wire, in order that the current, in traversing it without melting it, may act upon a soft iron rod placed in the interior of the bobbin. This iron rod is soldered to a brass stem of the same calibre, and of the same length, carrying at its free extremity a small pulley. On the opposite side the iron carries a small brass tube, with binding screws, into which is introduced one of the carbons, when the entire rod has been placed in the interior of the bobbin. Then a cord fixed to the lower cross piece, and rolling over a pulley of large diameter, is able to serve as a support to the movable iron rod, running in the groove of the little pulley. For this purpose, it only requires that a counterpoise placed at the end of the cord shall be enabled to be in equilibrio with it. The metal cross piece which occupies the upper part of the apparatus, carries a small brass tube, which descends perpendicularly in front of the carbon that is carried by the electro-magnetic stem, and into which is also introduced a carbon crayon. By means of a very simple adjustment, this tube may besides be easily regulated, both for its height and for its direction; and consequently the two carbons may be placed very exactly above one another. The apparatus being adjusted, we place one of the two metal columns of the apparatus in connection with one of the poles of the pile, and cause the other pole to abut upon the copper wire of the bobbin (one end of which is soldered upon its socket). The current then passes from the bobbin to the lower carbon by the rod itself that supports it, and passing over the interval separating the two carbons, it arrives at the other pole of the pile by the upper cross piece of the apparatus and the metal column, to which one of the conducting wires is attached.

So long as the current is passing and producing light, the bobbin reacts upon the iron of the electro-magnet rod, which carries the lower carbon and attracts it on account of the magnetic reaction that solenoids exercise over a movable iron in their interior. It is this which gives to the carbons a *separation sufficient for the luminous effect.*

But immediately the current ceases to pass, or is weakened, in consequence of the consumption of the carbons, this attraction ceases, and the movable carbon, acted on by the counterpoise, is found to be drawn on and raised until the current passes again; equilibrium is again established between the two forces, and the carbons may be employed again. Thus, in proportion as the light tends to decrease, the counterpoise reacts; and this it is that always maintains the intensity of the light equal.

M. Breton has an apparatus which differs somewhat from the above, and M. Foucault has also devised a very ingenious modification.

M. Duboscq has made by far the most successful arrangement, for a description of which we are indebted to *De la Rive's Treatise on Electricity*, translated by C. V. Walker.

The two carbons, between which the light is developed, burn in contact with the air, and shorten at each instant; a mechanism is consequently necessary, which brings them near to each other, proportionally to the progress of the combustion;

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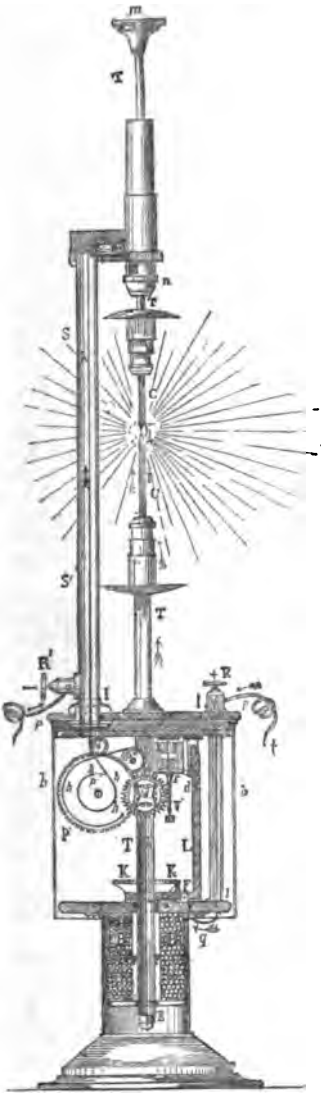

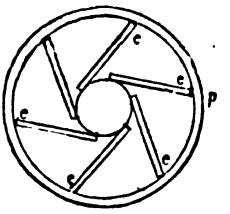

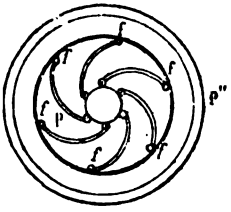

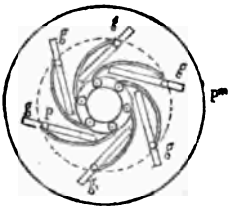

and since the positive carbon suffers a more rapid combustion than the negative, it must travel more rapidly in face of this latter; and this in a relation which varies with the thickness and the nature of the carbon. The mechanism must satisfy all these exigencies. The two carbons are unceasingly solicited towards each other, the lower carbon by a spiral spring, that causes it to rise, and the upper carbon by its weight, which causes it to descend. The same axis is common to them.

The galvanic current is produced by a Bunsen's pile of from 40 to 50 elements:

it arrives at the two carbons, as in apparatus already known, passing through a hollow electro-magnet, concealed in the column of the instrument. When the two carbons are in contact, the circuit is closed, the electro-magnet attracts a soft iron, placed at the extremity of a lever, which is in gear with an endless screw. An antagonist spring tends always to unwind the screw as soon as a separation is produced between the two carbons; if it is a little considerable, the current no longer passes, the action of the spring becomes predominant, the screw is unwound and the carbons approach each other until the current, again commencing to pass between the two carbons, the motion that drew them towards each other is relaxed in proportion to the return of the predominance of the electricity over the spring; the combustion of the carbons again increases their distance, and with it the superior action of the spring; hence follows again the predominance of the spring, and so on. These are alternatives of action and reaction, in which at one time the spring, at another time the electricity, has the predominance. On an axis, common to the two carbons, are two pulleys: one, the diameter of which may be varied at pleasure, communicates by a cord with the rod that carries the lower carbon, which corresponds with the positive pole of the pile; the other, of invariable diameter, is in connection with the upper or negative carbon. The diameter of the pulley, capable of varying proportionately to the using of the carbon, with which it is in communication, may be increased from three to five. The object of this arrangement is to preserve the luminous point at a convenient level, whatever may be the thickness or the nature of the carbons. It is only necessary to know that at each change of kind or volume of the carbon, the diameter of the pulley must be made to vary. This variation results from that of a movable drum, communicating with six levers, articulated near the centre of the sphere; the movable extremity of the six arms of the lever carries a small pin, which slides in cylindrical slits. These slits are oblique in respect of the sphere; they form inclined planes. A spiral spring always rests upon the extremity of the levers; so that, if the inclined planes are turned towards the right, the six levers bend towards the centre, and diminish the diameter. If, on the contrary, they are turned towards the left, the diameter increases, and with it the velocity of the translation of the carbon, which communicates with the pulley. We may notice, in passing, that this apparatus is marvellously adapted to the production of all the experiments of optics, even the most delicate; and that, in this respect, it advantageously supplies the place of solar light. As it is quite impossible to describe accurately the minute arrangements of this instrument, the letters of reference have not been used in the text.

Dr. Richardson informs us, that although Mr. Grove calculated, some years ago, that for acid, zinc, wear and tear, &c. of batteries, a light equal to 1444 wax candles could be obtained for about 3*s.* 6*d.* per hour, the cost of the light employed for about five minutes at Her Majesty's Theatre, as an incident in the ballet, which was obtained by employing 75 cells of Callan's battery of the largest size, was said to be 2*l.* per night, or at the rate of 20*l.* per hour. In this calculation we expect we have not a fair representation of all the conditions. To obtain a light for ten minutes, a battery as large must be used as if it were required to be maintained in activity for hours—and probably the battery was charged anew every evening. There can be no doubt but the cost of light or of any other *force* from electricity, with our present means of producing it, must be greatly in excess of any of our ordinary means of producing illumination. For a consideration of this subject, see ELECTRO-MOTIVE ENGINES. Mr. Grove proposed a light which should be obtained from incandescent platinum, but the objection to this was, that after a short period, the platinum broke up into small particles, the electric current entirely disintegrating the metal. Mr. Way has lately exhibited a very continuous electric light, produced from a constant flow of mercury rendered incandescent by the passage of the electric current.

ELECTRIC WEAVING. M. Bonelli devised a very beautiful arrangement, by which all the work of the Jacquard loom is executed by an electro-magnetic arrangement. The details of the apparatus would occupy much space in the most concise description, and as the invention has not passed into use, although M. Froment has modified and improved the machine, we must refer those interested in the subject to the full description given in *De la Rive's Treatise on Electricity* by *Walker*.

ELECTRO-GILDING BATH. See CYANIDES.

ELECTRO-METALLURGY. The art of working in metals was carried on exclusively by the aid of fire until the year 1839. At that epoch a new light dawned upon the subject; considerable interest was excited in the scientific world, and much astonishment among the general public by the announcement that electricity, under proper management, and by most easy processes, could supersede the furnace in not a few operations upon metals; and that many operations with metals, which could scarcely be entertained under the old condition of things, might be placed in the hands of a child, when electricity is employed as the agent.

Public attention was first directed to the important discovery by a notice that appeared in the *Athenæum* of May 4, 1839, that Professor Jacobi of St. Petersburg had "found a method of converting any line, however fine, engraved on copper, into a relief, by galvanic process." Jacobi's own account of the matter was that, while at Dorpat, in February, 1837, prosecuting his galvanic investigations, a striking phenomenon presented itself, which furnished him with perfectly novel views. Official duties prevented his completing the investigation, thus opened out to him, during the same year; and it was not until October 5, 1838, that he communicated his discovery, accompanied with specimens, to the Academy of Sciences at St. Petersburg; an abstract of which paper was published in the *German News* of the same place on October 30 of the same year. And in a letter of Mr. Lettsom, dated February 5, 1839, the nature of the discovery is thus given in the following March number of the *Annals of Electricity*. Speaking of a recent discovery of Professor Jacobi's he says, "He observed that the copper deposited by galvanic action on his plates of copper, could by certain precautions be removed from those plates in perfect sheets, which presented in relief most accurately every accidental indentation on the original plate. Following up this remark, he employed an engraved copper-plate for his battery, caused the deposit to be formed on it, and removed it by some means or other; he found that the engraving was printed thereon in relief (like a woodcut) and sharp enough to print from." This paragraph does not appear to have caught the eye of the public so readily as the briefer note that appeared a couple of months later in the *Athenæum*.

On May 8, or four days after the appearance of the notice in the *Athenæum*, Mr. Thomas Spencer gave notice to the Polytechnic Society of Liverpool that he had a communication to make to the society relative to the application of electricity to the arts. He subsequently desired to communicate the result of his discoveries to the British Association whose meeting was at hand; but, for some cause, which does not appear, the communication was not made; and it eventually was made public, as at first proposed, through the Polytechnic Society of Liverpool, on September 12, 1839. In the meantime, namely on May 22, Mr. C. J. Jordan, referring to the notice in the *Athenæum*, wrote to the *Mechanics' Magazine* that, at the commencement of the summer of 1838, he had made "some experiments with the view of obtaining impressions from engraved copper-plates by the aid of galvanism." His letter describing this process appears in the number for June 8. It occurred to him, from what he had gathered from previous experience, that an impression might be obtained from an engraved surface; and so it was, "for on detaching the precipitated metal, the most delicate and superficial markings, from the fine particles of powder used in polishing to the deeper touches of a needle or graver, exhibited their correspondent impressions in relief with great fidelity."

Mr. Spencer in his communication, besides noticing the fidelity with which the traces on an original plate were copied, recorded the case of a copper-plate that had become covered with precipitated copper, excepting in two or three places, where by accident some drops of varnish had fallen; whence it occurred to him, and experiment confirmed his conjecture, that a plate of copper might be varnished, and a design made through the varnish with a point, and copper might be deposited upon the metal at the exposed part, and thus a raised design be procured.

In the *Philosophical Magazine* for December, 1836, Mr. De la Rue, after describing a form of voltaic battery, refers to the well-known condition on which the properties of the battery in question mainly depend, that "the copper-plate is also covered with a coating of metallic copper, which is continually being deposited;" and he goes on to describe that "so perfect is the sheet of copper thus formed, that being stripped out, it has the counterpart of every scratch of the plate on which it is deposited." Daniell himself, whose battery is here in question, noticed as he could not fail to do in common with all who had employed his battery to any extent, the same peculiarities; but it does not appear that either he or De la Rue, or any one else, to whom the phenomenon presented itself before Jacobi, Jordan, or Spencer, caught the idea of its applicability in the arts. It would also appear that the impression came with the greater vividness to the two latter; for, while but little time seems to have been lost to them in realising their idea, twenty long months elapsed between the time when the "perfectly novel views" first presented themselves to Professor Jacobi, and the time when his "well-developed galvanic production" was communicated to the Imperial Academy of Science. But, on the other hand, neither Mr. Jordan nor Mr. Spencer appear, as far as we are aware, to have been so sensible of the importance of the results to which they had arrived as to have taken any steps to secure them as an invention or to publish them, until their attention was aroused by the previous publication of the successes of Jacobi.

Jacobi's "Galvano-plastik," Smee's and also Shaw's "Electro-metallurgy," Walker's

"Electrotype Manipulation," four well-known works on the subject before us, present the different names under which the art is known; and from which it is gathered that metals may become, as it were, plastic under the agency of galvanic electricity, and may be worked and moulded into form. Voltaic pairs are described in general terms in the article on ELECTRO-TELEGRAPHY. The particular voltaic pair which led to the discoveries now before us, here requires special notice; because, on the one hand, while in use for other purposes, it was the instrument which first directed attention forcibly to the behaviour of metals under certain conditions of electric current; and, on the other hand, it has been itself extensively used in electrotype operations. Professor Daniell first described his mode of arranging a voltaic pair in the *Philosophical Transactions* for 1836. *Fig.* 695 shows one cell complete of Daniell's combination, which from its behaviour is called a constant battery. A is a copper vessel; B a rod of zinc, contained in a tube C of porous earthenware.

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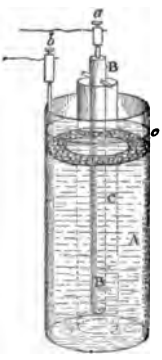

The liquid within the tube C is salt and water, in which case the zinc is in its natural state; or, sulphuric acid and water, in which case the zinc is amalgamated; the latter arrangement being the more active of the two. The liquid in the outer vessel A, consists of crystals of sulphate of copper, dissolved in water. At *c* is a perforated shelf of copper below the surface of the liquid, upon which are placed spare crystals of sulphate of copper, which dissolve as required, and serve to keep up the strength of the solution in proportion as the copper already there is extracted by the voltaic action hereafter to be described. *a* and *b* are screws, to which wires may be attached, in order to connect up the cell and convey the current from it into any desired apparatus. Certain chemical changes take place when this instrument is in action; oxygen from the water within the porous tube combines with zinc, making oxide of zinc, which enters into combination with sulphuric acid, producing as a final result sulphate of zinc; hydrogen is liberated from water in the outer cell, and itself liberates oxygen from oxide of copper, and combines with it producing water, and leaving copper free. As far as the metals are concerned, zinc is consumed *from* the rod B, at the one end, and copper is liberated *upon* the plate A, at the other end. These actions are slow and continuous; and the copper, as it is liberated atom by atom, appears upon the inner surface of the cell; and after a sufficient quantity has been accumulated, may be peeled off or removed; when it will be found to present the marks and features of the surface from which it has been taken, and which, as we have already said, arrested the attention of many into whose hands this instrument fell. A slight modification of the above arrangement gives us a regular electrotype apparatus. The cell *c* in this arrangement (*fig.* 696), is of glass or porcelain, or gutta percha, filled as before with a saturated solution of sulphate of copper, to which a little free acid is generally added; it is provided with a shelf or other means of suspending crystals of sulphate of copper. A zinc rod *z* is placed in a porous tube *p*, as already described; and *m*, the other metal of the voltaic pair, is suspended in the copper solution and connected with the zinc *z* by the wire *w*. The electric current now passes; zinc is consumed, as in *fig.* 695, but copper is now deposited on the metal *m* front and back, and on as much of the wire *w* as may be in the liquid; or, if Mr. Spencer's precaution is taken of varnishing the wire and the back of the metal *m*, all the copper that is liberated will be accumulated on the face of *m*. If salt and water or very weak acid water is contained in the porous tube *p*, and the zinc *z* does not considerably exceed in size the metal *m*, the conditions will be complied with for depositing copper in a compact reguline form.

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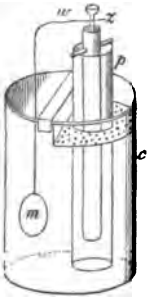

It is obvious that, with this arrangement, *m* may be a mould or other form in metal, and that a copy of it may be obtained in copper. Fusible metal, consisting of 8 parts of bismuth, 4 of tin, 5 of lead, and 1 of antimony; or 8 parts bismuth, 3 tin, and 5 lead, is much used for taking moulds of medals. The ingredients are well melted together and mixed; a quantity sufficient for the object in view is poured upon a slab or board and stirred together till about to set; the film of dross is then quickly cleared from the surface with a card, and the cold medal is either projected upon the bright metal, or being previously fitted in a block of wood is applied with a sudden blow. Moulds of wax or stearine variously combined, or more recently and better in many cases, moulds of gutta percha, are applicable to many purposes. But, as none of these latter materials conduct electricity, it is ne-

cessary to provide them with a conducteous surface. Plumbago or black lead is almost universally employed for this purpose; it is rubbed over the surface of the mould with a piece of wool on a soft brush, care being taken to continue it as far as to the conducting wire, by which the mould is connected with the zinc. With moulds of solid metal, the deposit of copper commences throughout the entire surface at once; but, with moulds having only a film of plumbago for a conductor, the action commences at the wire and extends itself gradually until it has been developed on all parts of the surface.

The nature of the electro-chemical decompositions that are due to the passage of voltaic currents through liquids, especially through liquids in which metal is in certain forms contained, can be best understood by studying the arrangement that is most commonly used in the arts, wherein the voltaic apparatus, from which the electric current is obtained, is distinct and separate from the vessel in which the electro-metallurgical operations are being brought about. Such an arrangement is shown in *fig.* 697, where A is a Daniell's cell, as in *fig.* 695; and B a trough filled with

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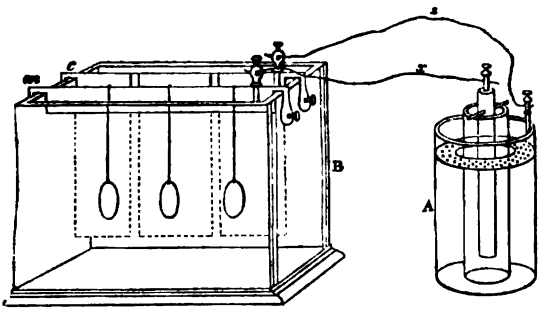

an acid solution of sulphate of copper; *m* is a metal rod, on which the moulds are hung; and *c* a metal rod, upon which plates of copper are hung facing the moulds; the copper-plates are connected by the wire *z* with the copper of the battery cell, and the moulds by the wire *x* with the zinc rod. The voltaic current is generated in the cell A, and its direction is from the zinc rod, through the solutions to the copper of the cell; thence by the wire *z* to the plates of copper *c*; through the sulphate solution to the moulds *m*; and thence by the wire *x* to the zinc rod. In this arrangement, no shelf is necessary in the trough B for crystals of sulphate of copper to keep up the strength of the solution; for the nature of the electro-chemical decompositions is such, that in proportion as copper is abstracted and deposited upon the moulds *m*, other copper is dissolved into the solution from the plates *c*. Water is the prime subject of decomposition. It is a compound body, consisting of the gases oxygen and hydrogen, and may be represented by *fig.* 698, where the arrows show the direction in which the current, by the wire *p*, enters the trough B of *fig.* 697 by the plate of copper C, and passes through the water in the direction shown, and leaves it after traversing the mould by the wire *n*. Two *atoms* of water O H and O′ H′, as bracketed 1 and 2, are shown to exist before the electric current passes; and *two* atoms, one of water H O′ (bracketed 1′), and one of oxide of copper *o c*, exist after the action. On the one hand an atom of copper C has come into the solution; and, on the other hand, the atom of hydrogen H′, belonging to the second atom of water, is set free and rises in the form of gas. The explanation is to show that oxygen is liberated where the current enters, and combines there in its nascent state with *copper*; it would not have combined, for instance, with gold or platinum. We might easily extend this symbolical figure, and show how that, when free sulphuric acid is in the solution, the oxide of copper on its formation combines with this acid to produce the sulphate of copper required; and how, when free sulphate of copper is present, the hydrogen, instead of being freed in the form of gas, combines with oxygen of the oxide of copper, and liberates the metal, which in its nascent state is deposited on the mould, and produces the electrotype copy of the same. One battery cell is sufficient for working in this way in copper; it is increased in size in proportion to the size of the object operated upon. And, although for small subjects, such as medals, a vertical arrangement will act very well; for large objects, it has been often found of great

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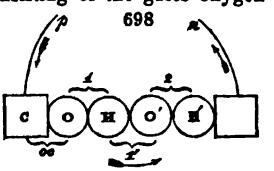

advantage to adopt a horizontal arrangement, placing the mould beneath the copper-plate. The varying density of a still solution in the vertical arrangement is not without its effect upon the nature of the deposit, both on its character and its relative thickness. This has been in some instances obviated, and the advantage of the vertical method retained by keeping the solution in motion, either by stirring or by a continuous flow of liquid.

We have described principally Daniell's battery as the generating cell in Electro-metallurgical operations; but Mr. Smee's more simple arrangement of platinized silver and zinc, excited with diluted sulphuric acid, has been found in practice more economical and convenient.

Fig. 699 is a Smee's cell; a vessel of wood, glass, or earthenware, contains diluted sulphuric acid, one in eight or ten, a platinised silver plate s, sustained by a piece of wood *w*, with a plate of zinc z z on each side, so as to turn to useful account both sides of the silver plate. The zinc plates are connected by the binding screw *b*. Platinization consists in applying platinum in fine powder to the metallic surface. When hydrogen is liberated by ordinary electric action upon a surface so prepared, it has no tendency to adhere or cling to it; but it at once rises, and in fact gets out of the way, so that it never, by its presence or lingering, interferes with the prompt and ready continuance of the electric action; and in this way, the amount of supply is well kept up.

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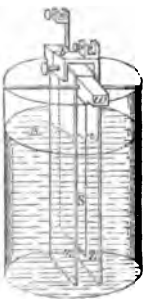


Platinization is itself another illustration of working in metal by electricity. A few crystals of chloride of platinum are dissolved in diluted sulphuric acid. A voltaic current is made to enter this solution by a plate of platinum and to come out by a silver plate. Two or three Daniell's or Smee's cells are necessary for the operation. The chloride of platinum is decomposed, and the metal is deposited upon the silver plate; not, however, in the reguline compact form, as in the case of copper, but in a state of black powder in no way coherent. This affords also an illustration of the different behaviour of metals under analogous circumstances. Copper is of all metals the most manageable; platinum is among the more unmanageable.

Mr. C. V. Walker has, with great advantage, substituted graphite for silver. The material is obtained from gas retorts, and is cut into plates a quarter of an inch thick, or thicker, when plates of a larger size are cut. He platinizes these plates in the usual way as above described, and deposits copper on their upper parts, also by electrotype process, and solders a copper slip to the electrotype copper, in order to make the necessary connection.

With the exception of silver and gold, copper is the metal which has been most extensively worked by these processes.

SEALS are copied by obtaining impressions in sealing-wax, pressing a warm wire into the edge for a connection; rubbing blacklead over the wax to make the surface conducteous; fastening a slip of zinc to the other end of the wire; wrapping the zinc in brown paper, and putting the whole into a tumbler containing sulphate of copper, a little salt-water having been poured into the brown paper cell.

PLASTER OF PARIS MEDALLIONS may be saturated with wax or stearine, and then treated, if small, like seals; if large, in a distinct trough, as in *fig.* 697. In this case the copy is in intaglio, and may be used as a mould for obtaining the facsimile of the cast. More commonly, the cast is saturated with warm water, and a mould of it taken in wax, stearine, or gutta percha. This is treated with blacklead, and in other respects the same as seals.

WOODCUTS are treated with blacklead, and a copper reverse is deposited upon them. This is used as a mould to obtain electrotype duplicates, or as a die for striking off duplicates.

STEREOTYPE PLATES are obtained in copper by taking a plaster copy of the type, treating it plaster fashion, depositing a thin plate of copper upon it, and giving strength by backing up with melted lead.

OLD BRASSES may be copied by the intervention of plaster.

EMBOSSED CARDS OR PAPER may be copied by first saturating with wax and then using blacklead.

FRUIT may be copied by the intervention of moulds, or may be covered with copper. LEAVES, TWIGS, and BRANCHES may have copper deposited upon them. The same for STATUETTES, BUSTS, and STATUES.

Leaves and flowers are furnished with a conducting surface by dipping them into a solution of phosphorus in bisulphuret of carbon, and then into a solution of nitrate of silver. Silver is thus released in a metallic state upon their surface.

PLASTER BUSTS, &c., have been copied in copper, by first depositing copper on the plaster prepared for this operation; when thick enough, the original bust is destroyed, the copper shell is filled with sulphate of copper, as in *fig.* 697, and copper is deposited on its inner surface till of sufficient thickness; the outer shell is then removed.

TUBES and VESSELS of capacity do not appear to have been profitably multiplied by electrotype.

PLATES have been prepared for the ENGRAVER to work on by depositing copper on polished copper-plates, and removing the deposits when thick enough.

For the multiplication of ENGRAVED COPPER PLATES, the electrotype process has been very extensively adopted. A reverse of the plate is first obtained by the deposition of copper; this serves as a mould, from which many copies of the original plate are obtained by depositing copper upon it, and then separating the two. The mode practised by the Duke of Leuchtenberg is to print from an engraved plate on very thin paper with a mixture of resin of Damara, red oxide of iron, and essence of turpentine. While the impression is wet, the paper face downwards is pressed upon a polished plate of copper. When dry the paper is washed away, and the impression remains. An electrotype copy from this is obtained in intaglio, and is fit for the use of the printer.

GALVANOGRAPHY is a picture drawn originally in varnish on the smooth plate, and then treated in a similar way to the above.

The PLATES on rollers used by CALICO PRINTERS have been multiplied like engraved plates.

GLYPHOGRAPHY is a name given by Mr. Palmer to his process. He blackens a fair copper-plate with sulphuret of potassium, covering it uniformly with a coating of wax and other things, then draws the design through the wax with fine tools. From the plate thus prepared, an electrotype is taken in the usual way, and is backed up and mounted as an electro-glyphic cast to print from as from a wood block. For a *stereo-glyphic* cast to work from as a stereotype plate, a plaster copy is taken of the original drawing, the high lights are cut out, and then an electrotype copy is made.

ELECTRO-TINT is done by drawing with wax or varnish any design on a fair copper-plate, and making an electrotype copy for the printer's use.

FERN-LEAVES, &c., are copied by being laid on a sheet of soft gutta percha, pressed into the surface by a smooth plate to which pressure is applied, and then removed in order to subject the gutta percha mould to the electrotype process. This is NATURE PRINTING, which see.

MM. Auer and Worring have copied LACE, EMBROIDERY, flowers, leaves of trees, entire plants, fossils, insects, &c., in their natural relief, by laying the objects upon a plate of copper, after having soaked them in spirits of wine and turpentine so as to fix them. A plate of clean lead is laid over, and, on being pressed, an intaglio copy is produced on it of the object. From this an electrotype is obtained.

UNDERCUT MEDALLIONS, &c., are copied in elastic moulds made of treacle and glue in the proportions of 1 to 4. Masks and busts may also be obtained in such moulds.

ELECTRO-CLOTH was made by saturating the fibre of canvass or felt, making it conducteous in the usual way; it was proposed in place of tarpaulins as a water-tight cover.

RETORTS and CRUCIBLES, &c., of glass or porcelain, have been successfully coated with electrotype copper by first varnishing or otherwise preparing the surface to retain the black lead, and then treating them as usual.

SOLDERING COPPER surfaces has been accomplished by galvanic agency. The ends to be united are placed together in the solution of sulphate of copper, and connected with the battery as for ordinary deposition. Parts not included in the process are protected off by varnish; copper is then deposited, so as to unite the separate pieces into one.

IRON may be COATED WITH COPPER. But here a new feature comes into view. Sulphuric acid leaves the copper of the sulphate, combines with iron and deposits copper on its surface without the aid of the voltaic apparatus. The iron surface is imperfectly covered with copper, no firm perfect deposit occurs. In order to obtain solid deposits of copper on iron, it is necessary to use a solution that has no ordinary chemical reaction upon iron. Cyanide of copper is used, which may be obtained by dissolving sulphate of copper in cyanide of potassium. This solution requires to be raised to and retained at a temperature not greatly below 200°, in order to give good results.

ELECTRO-ZINCING is applied to surfaces of iron, in order to protect them from corrosion. A solution is made of sulphate of zinc, which is placed in a trough B,

fig. 697. Two or three battery cells are required. The iron to be zinced is connected with the zinc end of the battery, and a plate of zinc with the copper end.

VOLTAIC BRASS does not appear to have been obtained in a solid distinct form, but has been successfully produced as a coating upon a copper surface. Separate solutions are made of sulphate of copper and of sulphate of zinc in cyanide of potassium. The two solutions are then mixed, and placed in a decomposing trough. Two or three cells of a battery are used, and a brass plate connected with the copper end. An electrotype copper medal or other prepared surface is connected with the zinc. Brilliant and perfect brass soon appears, and will deposit slowly for some hours; but after a while, the character of the solution changes, and copper appears in place of brass.

This hasty glance at the leading applications of this art will give an idea of its utility. It also comes into play in cases where least suspected. Pins were tinned by electrotype long before the art was known. Brass pins are thrown into solution of tin in cream of tartar, and are unchanged; but when a lump of tin is thrown among them, a voltaic pair is formed, and tin is deposited on all the heap. Any stray pins detached from the mass, escape the influence. Space would fail us were we to go through the list of crystalline and of simple bodies formed by these processes; as for instance, octahedral crystals of protoxide of copper; tetrahedral crystals of proto-chloride of copper; octahedral crystals of sulphide of silver; crystals of subnitrate of copper; bibasic carbonate of copper, and others too numerous to name, have all been formed by slow voltaic actions. The alkaline metals, potassium, sodium, &c., were first obtained by Davy in the galvanic way; magnesium, barium, aluminium, calcium, &c., are obtained by M. Bunsen by operating upon the chlorides of these metals either in solution or in a state of fusion.

ELECTRO-ETCHING is produced at the place where the current *enters* the decomposing trough, as at the copper-plates *c* of *fig.* 697. A plate of copper is prepared as if for the graver; its face is then covered with an etching ground of asphalte, wax, black pitch, and burgundy pitch; and its back with varnish. The design is then traced through the etching ground with a fine point; the plate is then placed in the trough B, containing either sulphate of copper or simply diluted sulphuric acid, and connected with the copper of the battery. After a few minutes it is removed, and the fine lines are stopped out with varnish; it is then replaced, and again, after a few minutes is removed, and the darker shades are stopped out; the parts still exposed are again subjected to the action, and the etching is complete. When the ground is removed, the design will be found etched upon the copper-plate ready for the printer.

DAGUERREOTYPE ETCHING is a delicate operation, and requires much care. The solution employed by Professor Grove was hydrochloric acid and water in equal parts, and a battery of two or three cells.

Platinized silver is used in face of the daguerreotype, instead of copper. The result comes out in about half a minute. An oxy-chloride of silver is formed, and the mercury of the plate remains untouched.

A PHOTO-GALVANO-GRAPHIC Company has been formed in London for carrying out the process of Paul Pretsch. He makes solutions of bichromate of potash in glue water, or in solution of gelatine, instead of in pure water. He then treats the glass or plate with these, and in the usual way takes a picture. He washes the gelatine picture with water, or solution of borax or carbonate of soda, which leaves the picture in relief; when developed, he washes with spirits of wine, and obtains a sunk design. The surfaces thus prepared, or moulds made from them in one or other of the modes already described, are placed in a galvano-plastic apparatus for obtaining an engraved plate from which to print. See PHOTO-GALVANOGRAPHY.

The Duke of Leuchtenberg prepares a plate for etching by leaving the design on the ground, and removing the ground for the blank parts. When his electrotype operation is complete, the design is in relief instead of being in intaglio as in ordinary etching.

METALLO-CHROMES consist of thin films of oxide of lead, deposited sometimes on polished plates of platinum, but most commonly on polished steel plates. The colours are most brilliant and varied. Nobili is the author of the process.

A saturated solution of acetate of lead is prepared and placed in a horizontal trough. Three or four battery cells are required. A steel plate is laid in the acetate of lead with its polished surface upward, and is connected with the copper of the battery. If a wire is connected with the zinc end of the battery, and held over the steel plate in the solution, a series of circles in brilliant colours, arise from the spot immediately beneath the wire, and expand and spread, like the circles when a stone is thrown into a pond. Silver-blond is the first colour; then fawn-colour, followed by the various shades of violet, and indigoes and blues; lake, bluish lake,

green and orange, greenish violet, and passing through reddish yellow to rose-lake, which is the last colour in the series.

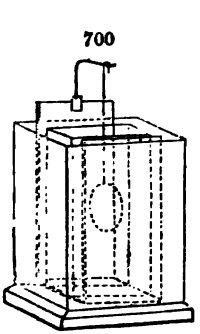
According to the shape of the metal by which the current enters — be it a point, a slip, a cross, a concave, or a convex disc — so is the form of the coloured figure varied. And if, in addition to this, a pattern in card or gutta percha is cut out and interposed between the two surfaces, the action is intercepted by the portions not removed, and the design is produced on the steel plate, in colours, that may be greatly varied, according to the duration of the experiment. The different colours are due to the different thicknesses of the thin films of peroxide of lead.

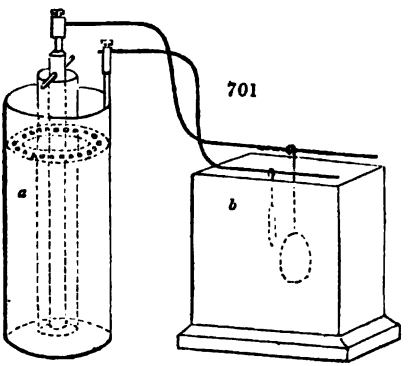
M. Becquerel proposed the deposit of peroxide of lead, and also the red peroxide of iron, for protecting metals from the action of the atmosphere. For the latter, proto-sulphate of iron is dissolved in ammonia solution, and operated upon by two or three batteries.

The most important application of electro-metallurgy in the arts has been for PLATING and GILDING, which is most extensively carried on both at home and abroad. Results that were unattainable, and others attainable only at great cost, are readily produced by this mode of manipulating. The liquids most in use are the cyanide solutions, first introduced by Messrs. Elkingtons. They are prepared in various ways. Cyanide of potassium is added carefully to dilute solution of nitrate of silver; and the white deposit of cyanide of silver is washed, and then dissolved in other cyanide of potassium; or lime water is added to the nitrate solution, and the brown deposit of oxide of silver is washed and, while moist, is dissolved in cyanide of potassium; or common salt is added to the nitrate solution, and the white deposit of chloride of silver is washed and dissolved in cyanide of potassium. Or a solution of cyanide of potassium is placed in the trough B, *fig.* 697; and the current from three or four cells is passed into it from a silver plate at *c*, which combines with and is dissolved into the liquid, converting it into a cyanide of silver solution. To prevent silver being abstracted by deposition at *m*, as the current leaves the trough, the metal at *m* is placed within a porous cell of cyanide solution, so as to limit the action.

Gold solution is obtained by dissolving the anhydrous peroxide of gold in cyanide of potassium, or by treating chloride of gold with cyanide of potassium, or by using a gold plate and a voltaic current with a solution of cyanide of potassium in the same way as described for silver; and allowing the action to continue until the solution is sufficiently strong of gold. With these solutions electro-plating and gilding are readily accomplished. There are other solutions more or less valuable, which will be found in the books that treat upon the subject.

Fig. 700 shows a single cell arrangement for plating. The zinc is outside, and is bent to embrace both sides of the porous cell. The article to be plated is within this





cell; because, being the vessel of smaller capacity, less of the more valuable silver solution is required, and there is less of loss or waste. The same holds good in a greater degree of gold. In a few minutes, the article is covered with silver. If a few drops of sulphuret of carbon are added to the silver solution, the silver is deposited bright. Gold does not come down quite so rapidly as silver.

Except for mere experiment, these operations are better accomplished and with less waste by using distinct batteries, as *a*, *fig.* 701, the solution of gold or silver being in a distinct trough *b*, plates of silver or gold, as the cases may be, being suspended in front of the article to be coated. One or two cells, according to the results required, are used for plating; and three or four for gilding. But gilding is never so

well accomplished as it is with hot solutions. The modes of keeping solutions hot vary with circumstances, and with the extent of the operations. *Fig.* 702 is an

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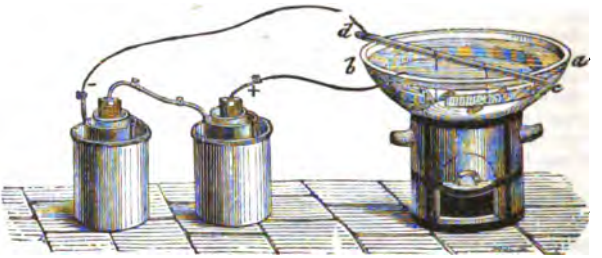

arrangement for operations on a small scale. The vessel *a b*, containing the gold solution, rests over a small stove or spirit-lamp. The objects to be gilt are suspended by wires to the conducting rod *d*, in connection with the zinc end of the battery; and the gold wire or plate *c* is connected with the other end. A temperature of from 100° to 200° is desirable; the higher temperatures require fewer battery cells; with the highest, one will suffice. The solution of course evaporates under the influence of heat; and distilled water must be added to supply the loss, before each fresh operation.

Plating and gilding is successfully and, in point of economy, advantageously carried on at Birmingham, in more than one manufactory, by means of magneto-electricity. In the article on ELECTRIC-TELEGRAPHY will be found a description of this form of electric force; and the means by which it is produced. An electro-magnet is set in motion in front of the poles of a permanent magnet, in such a manner that the soft iron core of the electro-magnet becomes alternately a magnet and not a magnet; in the act of becoming a magnet, it raises up a current in one direction in the wire with which it is wound; in the act of ceasing to be a magnet, it raises up a current in the reverse direction. The ends of the wire are led away and insulated. The instru-

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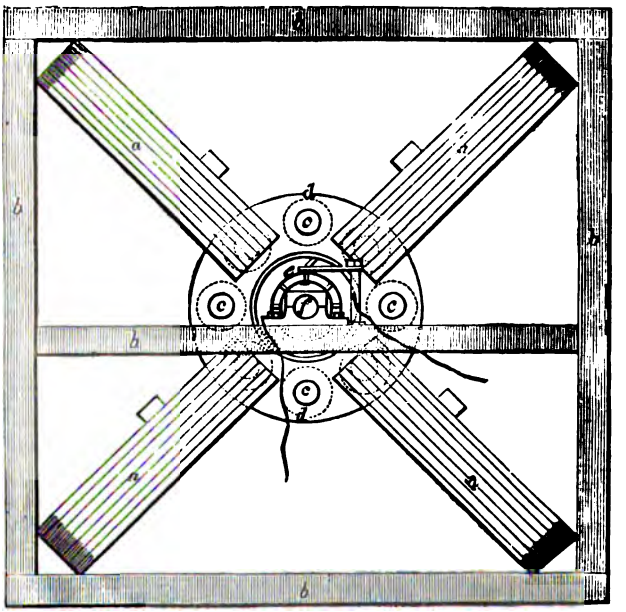


ment is fitted with a commutator, so adjusted that it collects the currents from the ends of the wire, and guides them in a uniform direction into the vessel that contains the solution and articles to be gilded or plated. In practice, a single machine consists

of many electro-magnets grouped together, and many powerful magnets for exciting them; by which means a continuous flow of a large amount of electricity is obtained. *Fig.* 703 is an illustration of such an arrangement as adapted by Mr. Woolrich: *a a a a* are four clusters of permanent steel magnets, seen from above; *b b b b b* is the frame-work of the machine; *c c c c* are four bars of soft iron, wound with large size insulated copper wire; *d* is a circular disc, on which they are mounted, and which rotates on a vertical axis, of which *f* shows the upper end; *e* is the commutator, from which two wires are led off to the solution to be operated upon. The permanent magnets are U shaped; one pole only of each bundle is visible; the other is beneath the disc *d*, and its freight of electro-magnets *c c*, &c. The axis is set in rotation by a strap passing over the drum of a shaft of the steam-engine, that does the ordinary work in a factory; and the disc carries the electro-magnets between the poles of the permanent magnets, and exposes them to the most favourable action of these poles. The number of coils and magnets vary in proportion to the work required. By this arrangement, not only does each coil pass under the influence of many magnets, but each magnet acts successively on many coils; and a proportionate supply of electricity is the result.—C. V. W.

ELECTRO-MOTIVE ENGINES. The following remarks on this subject are an abstract of a communication read by the editor to the *Institution of Civil Engineers*, for which they awarded him their Telford Medal.

Numerous electro-magnetic machines have been made, but a few only of these require to be described. In 1832, Salvatore Dal Negro published an account of the attempts made by him in this direction. As Dal Negro's engine was of a very simple and effective kind, the Professor's description of it may be quoted:—"As I had been successful in producing temporary magnets of very great power, with very small electro-motors, I endeavoured to apply this power to moving machinery. I will now briefly state by what means I endeavoured to set a lever in motion. I first used a magnetic steel bar, placed vertically between one end of a temporary magnet. The bar vibrated from the attractions and repulsions which took place between its north pole and the north and south poles of the electro-magnet. In the same way a motion may be effected in a horizontal plane. I also set in motion a similar bar, by allowing a piece of iron, set free from the magnet at the moment when its power became = 0 to fall on one of its ends, after this it was immediately re-attracted. This can be effected in two ways: the one may be employed when a quick motion is to be produced and the second when a greater force is wanted; in the first case the weight falls only just out of the power of the magnet's attraction, and the instant the weight has fallen upon the bar, or lever, it is re-attracted by the magnet that the action may be repeated: it is always small in comparison with that which the magnet cannot support whilst in contact. In the second case the whole weight which the magnet can carry is employed, and use is made of the force which draws it to the magnet." Upon this was founded several other attempts, particularly one by Dr. Schulthess, who was so satisfied with the result, that he wrote in 1833:—"If we consider that electro-magnets have already been made, which were capable of carrying 20 cwts., and that there is no reason to doubt that they may be made infinitely more powerful, I think I may boldly assert, that electro-magnetism may certainly be employed for the purpose of moving machines." Professor Botto of Turin, also employed "a lever put in motion (in the manner of a metronome) by the alternating of two fixed electro-magnetic cylinders, exerted on a third movable cylinder, connected with the lower arm of the lever, the upper part of which maintains a metallic wheel, serving in the ordinary way, as a regulator in a continuous gyratory motion." It will be evident to any one who has observed the motion of many of the electric clocks, that this is in several respects similar to the pendulous motions adopted.

In 1835, Professor Jacobi, of St. Petersburg, published an account of his experiments, which were carried out on a large scale, regardless of cost, at the expense of the Emperor Nicholas. His first idea was to employ the attractive and repellant powers of magnetic bars, so that he might obtain an advancing and receding motion, which could be easily changed into a continuous circular motion. A great many machines have been made upon this principle; but Jacobi, alone, as far as can be learned, has pointed out the true cause of their failure. "We know," he says, "the ill effects of shocks in the movements of machines, but there is here, another inconvenience which is not simply mechanical. The soft iron, by these repeated shocks and vibrations, gradually acquires at the surface of contact the nature of steel; there will be a considerable permanent magnetism, and the transient magnetic force which alone produces the movement, will be weakened in proportion. A number of experiments, which I have made upon the magnetic force of a bar of soft iron, bent into a horseshoe form, has shown me the great disadvantage of often repeated shocks, proceeding from the sudden contact of the armature."

Jacobi, finally setting aside all oscillating motions, produced a machine giving continuous circular motion, by fixing eight electro-magnetic bars on a disc, movable round an axis—and eight fixed bars similarly arranged upon a fixed platform. The arrangement of the bars admitted of much variety, provided it was exactly symmetrical, and that it allowed the poles to approach each other as nearly as possible. Arrangements were made, with much ingenuity, by which the poles of the magnets were inversed directly, and so that that inversion should take place precisely at that point where the bars were opposite each other. One hundred and forty-four inversions in the second were readily effected, and Jacobi declared it would be easy with his apparatus "to change, or to completely interrupt, the electric current, one thousand, or more, times in a second."

A machine constructed upon this principle was, at the desire and at the cost of an Imperial Commission, put on board a ten-oared shallop, equipped with paddle-wheels, to which the electro-magnetic engine communicated motion. The boat was 28 feet long, and 7½ feet in width, and drew 2½ feet of water. In general, there were ten or twelve persons on board, and the voyage on the Neva was continued during several entire days. By these experiments Jacobi was led to the conclusion, that a battery of 20 square feet of platinum would produce power equivalent to one horse; and the vessel went at the rate of four miles an hour. In 1839, Jacobi tried another experiment, with a battery of 64 platinum plates, each having 36 square inches of surface; when the boat, with a party of 14 persons on board, went against the stream at the rate of 3 miles an hour.

In 1837, Mr. Thomas Davenport, of the United States, constructed a rotary engine, in which permanent and electro-magnets were employed. Mr. Taylor, in 1839, patented an electro-magnetic engine, both in America and in this country, the principal novelty in which was, that instead of changing the poles of the magnets, the electric action was, at fixed rapid intervals, entirely suspended. In 1837, Mr. Davidson, of Edinburgh, constructed an engine, in which he produced motion by simply suspending the magnetism, without a change of the poles. Mr. Robert Davidson placed an electro-magnetic locomotive on the Edinburgh and Glasgow Railway; the carriage was 16 feet long, and 6 feet broad, and weighed about 5 tons. All the arrangements appear to have been very complete, but when put in motion on the rails, it was not possible to obtain a greater speed than four miles an hour.

Professor Page's electro-magnetic engine was for some time looked upon as a triumph. The fundamental principle of it is thus described: "It is well known that when a helix of suitable power is connected with the poles of a battery in action, an iron bar, within it, will remain held up by the induced magnetism, although the helix be placed in a vertical position; and if the bar is partly drawn out of the helix by the hand, it goes back with a spring, when the hand lets go its hold. This power,—the action of the helix upon the metallic bar within it,—is the power used in Page's engine." Professor Page exhibited one of his engines, of between 4 and 5 horse-power, at the Smithsonian Institution; the battery to operate with being contained within a space of 3 cubic feet. It was a reciprocating engine of 2 feet stroke, and the whole, including the battery, weighed about one ton. Professor Page stated, that the consumption of 3 lbs. of zinc per day would produce one horse-power. This statement requires further investigation.

Many similar attempts have been made, to construct effective machines to be moved by the power of the voltaic battery. Among others, Mr. Henley constructed an electro-magnetic engine of considerable power, for Mr. Talbot, and another for Professor Wheatstone. In these there were many ingenious mechanical arrangements, invented to overcome some of the difficulties hitherto encountered; but the physical conditions were similar to those already described. Mr. Talbot's engine was 3 feet 6 inches long, and 2 feet 6 inches wide; when excited by a Grove's battery, consisting of four cells with double plates of zinc, 9 inches by 6½ inches, platinum plates 9 inches by 5½ inches, excited by diluted sulphuric acid in the proportions of 1 to 4, and concentrated nitric acid, it drove a lathe, with which was turned a gun-metal pulley 5 inches in diameter; but in three quarters of an hour the battery was quite exhausted.

Mr. Hjörth, a few years since, exhibited in London a large machine, constructed somewhat on the principle of Page's; this, however, failed to produce any great mechanical effect, and it appears to have been abandoned. Dr. Lardner stated, in 1851, that M. Gustave Froment, of Paris, was using, with much advantage, an electro-magnetic engine in his workshops for turning lathes, planing machines, &c. Its use, however, appears to have been abandoned, on account of the great cost of the battery power.

Haukel and Fessel, on the Continent, the Rev. James William M'Gauley, Dr. Kemp, and others, in Great Britain, have, at different times, excited much attention by the ingenious machines which they have constructed.

Notwithstanding these numerous trials, and, connected with them, an almost infinite amount of experiment, it does not appear, that any satisfactory explanation has ever been given of the causes which have led to the abandonment of the idea of employing electricity as a motive power. It was mainly with the view of directing attention to these causes, that the essay read was written.

Electro-magnetism undoubtedly affords an almost unlimited power. An electro-magnet may be constructed which shall have a lifting power equal to many tons. It is probable, that there are limits beyond which it would not be possible to increase the power of electro-magnets; those limits have not yet been reached; but supposing them to be attained, there is nothing to prevent the multiplying of the number of electro-magnets in the arrangements. It may be stated, in connection with this part of the subject, that from experiments made with Hearder's magnetometer, it appears that the development of magnetism in iron observes some special peculiarities. These may be thus stated: — With the same electro-magnet there is, as the voltaic pairs in the battery are increased, a gradual increase of magnetic force. With from one to seven elements there appears an average excess of 31 lbs.; after this point, with the increase of battery power, by the addition of pair after pair of zinc and platinum elements, the production of power bears a decreasing ratio to the power employed, and at last, the addition of five elements was not found to produce an increase of effect equivalent to the value of one element. In all experiments, therefore, on electro-magnetic machines, the experimentalist has first to determine the utmost power which the soft iron is capable of assuming, in relation to,—1st. The number of coils of wire on the iron; and 2nd, the number of elements employed in the exciting source—the voltaic battery. The length of the iron and its thickness are also points demanding special considerations from the constructor of an electro-magnetic machine.

There remains now to examine the production of the power, Electro-Magnetism.

The electro-mechanician is dependent upon his battery, in the same way as a steam engineer is dependent upon his fire and his boiler, for the production of mechanical effect.

Voltaic batteries vary in their effects, and hence arise statements which differ widely from each other, as to the result obtained, by the destruction (? change of form) of a given quantity of metal in the battery.

Dr. Botto states, that 45 lbs. of zinc, consumed in a Grove's battery, are sufficient to work one-horse power electro-magnetic engine for twenty-four hours.

Mr. Joule says the same results would have been obtained, had a Daniell's battery been used, by the consumption of 75 lbs. of zinc.

It is impossible, on the present occasion, to enter into the theory of the voltaic battery, or to describe the varieties of arrangement which have been adopted for generating (developing) electrical force in the form of a current, with the greatest effect, at the smallest cost.

On this point the evidence of Jacobi may be quoted: — "With regard to the magnetic machine, it will be of great importance to weaken the effects of the counter current, without at the same time weakening the magnetism of the bars. It is the alternate combination of the pairs of plates in the voltaic pile, which permits us to increase the speed of rotation at will. We know the magnetic power of the current is not sensibly augmented by increasing the number of the pairs of plates, but the counter current is considerably weakened by its being forced to pass through a great many layers of liquid. In fact, on using twelve voltaic pairs, each, half a square foot, instead of four copper troughs, each with a surface two square feet, which I had hitherto used, the speed of rotation rose at least 250 or 300 revolutions in a minute."

Mechanical force, whether obtained in the form of man-power, horse-power, steam-power, or electrical-power, is the result of a change of form in matter. In the animal, it is the result of muscular and nervous energy, which is maintained by the due supply of food to the stomach. In the steam-engine, it is the result of vapour pressure, which is kept up by the constant addition of fuel to the fires, under the boilers. In the magnetic machine, it is the result of currents circulating through wires, and these currents are directly dependent upon the chemical change of zinc or of some other metal in the battery. Then,

Animal power depends on food.
Steam power depends on coal.
Electrical power depends on zinc.

An equivalent of coal is consumed in the furnace — that is, it unites its carbon with oxygen to form carbonic acid, and its hydrogen with oxygen to form water, and during this change of state the quantity of heat developed has a constant relation to the chemical action going on.

Mr. Joule has proved by a series of most satisfactory experiments, that: "The quantity of heat capable of increasing the temperature of a pound of water by one degree of Fahrenheit's scale is equal to, and may be converted into, a mechanical force capable of raising 838 lbs. to the perpendicular height of one foot."

Mr. J. Scott Russell has shown that in the Cornish boilers, at Huel Towan and the United Mines, the combustion of one pound of Welsh coal evaporates of water, from its initial temperature, 10·58° and 10·48° respectively. "But," says Mr. Joule, "we have shown that one degree is equal to 838 lbs. raised to the height of one foot. Therefore the heat evolved by the combustion of one pound of coal is equivalent to the mechanical force capable of raising 9,584,206 lbs. to the height of one foot, or to about ten times the duty of the best Cornish engines."

Such are the conditions under which heat is employed as a motive power. An equivalent of zinc is acted on by the acid in the cells of the battery, and is oxidised thereby. In this process of oxidation a given quantity of electricity is set in motion; but the quantity available for use, falls very far below the whole amount developed by the oxidation of the zinc. The electricity, or electrical disturbance, is generated on the surface of the zinc; it passes through the acidulated fluid to the copper plate or platinum plate, and in thus passing from one medium to another, it has to overcome certain mechanical resistances, and thus a portion of the force is lost. This takes place in every cell of the voltaic arrangement, and consequently the proportion of zinc which is consumed, to produce any final mechanical result, is considerably greater than it should be theoretically.

Joule gives as the results of his experiments, the mechanical force of the current produced in a Daniell's battery as equal to 1,106,160 lbs. raised one foot high, per pound of zinc, and that produced in a Grove's battery as equal to 1,843,600 lbs. raised one foot high, per pound of zinc.

It need scarcely be stated, that this is infinitely above what can be practically obtained. A great number of experiments, made by the Author some years since, enabled him to determine, as the mean average result of the currents, produced by several forms of battery power, that one grain of zinc, consumed in the battery, would exert a force equal to lifting 86 lbs. one foot high. Mr. Joule and Dr. Scoresby thus sum up a series of experimental results: "Upon the whole, we feel ourselves justified in fixing the maximum available duty of an electro-magnetic engine, worked by a Daniell's battery, at 80 lbs. raised a foot high, for each grain of zinc consumed." This is about one-half the theoretical maximum duty. In the Cornish engines, doing the best duty, one grain of coal raised 143 lbs. one foot high. The difference in the cost of zinc and coal need scarcely be remarked on. The present price of the metal is 35*l.* per ton, and coal can be obtained, including carriage to the engines, at less than 1*l.* per ton; and the carbon element does two-thirds more work than can possibly be obtained from the metallic one.

By improving the battery arrangements, operators may eventually succeed in getting a greater available electrical force. But it must not be forgotten, that the development of any physical force observes a constant law. Whether in burning coal in the furnace, or zinc or iron in the battery, the chemical equivalent represents the theoretical mechanical power. Therefore, the atomic weight of the carbon atom being 6, and that of the zinc atom being 32, it is not practicable, under the best possible arrangements, to obtain anything like the same mechanical power from zinc which can be obtained from coal. Zinc burns at an elevated temperature; in burning a pound of zinc there should be obtained, as heat, the same amount of mechanical power which is obtained as electricity in the battery. The heat being more easily applied as a prime mover, it would be far more economical to burn zinc under a boiler, and to use it for generating steam power, than to consume zinc in a voltaic battery for generating electro-magnetical power.

ELECTRO-PLATING AND GILDING IRON. Professor Wood, of Springfield, Massachusetts, in a paper, which he has communicated to the *Scientific American*, recommends the following as useful recipes for the electro-metallurgist. He says, "I believe it is the first time that a solution for plating direct on iron, steel, or Britannia metal has been published. In most of the experiments I have used Smee's battery; but for depositing brass I prefer a battery fitted up as Grove's, using artificial graphite—obtained from the inside of broken coal-gas retorts—in the place of platinum. With one large cell (the zinc cylinder being 8 *x* 3 inches, and excited with a mixture of one part sulphuric acid and twelve parts water, the graphite being excited with commercial nitric acid) I have plated six gross of polished iron buckles per hour with brass. I have also coated type and stereotype plates with brass, and find it more durable than copper-facing."

To prepare Cyanide of Silver.—1. Dissolve 1 oz. of pure silver in 2 oz. of nitric acid and 2 oz. of hot water, after which add 1 quart of hot water. 2. Dissolve

5 oz. of the cyanide of potassium in 1 quart of water. To the first preparation add by degrees a small portion of the second preparation, until the whole of the silver is precipitated, which may be known by stirring the mixture and allowing it to settle. Then drop into the clear liquid a very small quantity of the second preparation from the end of a glass rod; if the clear liquid is rendered turbid, it is a proof that the whole of the silver is not separated; if, on the other hand, the liquid is not altered, it is a proof that the silver is separated. The clear liquid is now to be poured off, and the precipitate, which is the cyanide of silver, washed at least four times in hot water. The precipitate may now be dried and bottled for use. *To prepare Cyanide of Gold.* — Dissolve 1 oz. of fine gold in 1·4 oz. of nitric acid and 2 oz. of muriatic acid; after it is dissolved add 1 quart of hot water, and precipitate with the second preparation, proceeding the same as for the cyanide of silver. *To prepare Cyanides of Copper and Zinc.*—For copper, dissolve 1 oz. of sulphate of copper in 1 pint of hot water. For zinc, dissolve 1 oz. of the sulphate of zinc in 1 pint of hot water, and proceed the same as for cyanide of silver. The electro-plater, to insure success in plating upon all metals and metallic alloys, must have two solutions of silver; the first to whiten or fix the silver to such metals as iron, steel, Britannia metal, and German silver; the second to finish the work, as any amount of silver can be deposited in a reguline state from the second solution. *First, or Whitening Solution.*—Dissolve 2½ lbs. (troy) of cyanide of potassium, 8 oz. carbonate of soda, and 5 oz. cyanide of silver in one gallon of rain or distilled water. This solution should be used with a compound battery, of three to ten pairs, according to the size of the work to be plated. *Second, or Finishing Solution.* — Dissolve 4½ oz. (troy) of cyanide of potassium, and 1½ oz. of cyanide of silver, in 1 gallon of rain or distilled water. This solution should be used with one large cell of Smee's battery, observing that the silver plate is placed as near the surface of the articles to be plated as possible.—N.B. By using the first, or whitening solution, you may insure the adhesion of silver to all kinds of brass, bronze, red cock metal, type metal, &c., without the use of mercury, which is so injurious to the human system. *To prepare a Solution of Gold.*— Dissolve 4 oz. (troy) of cyanide of potassium, and 1 oz. of cyanide of gold, in 1 gallon of rain or distilled water. This solution is to be used warm (about 90° Fahr.) with a battery of at least two cells. Gold can be deposited of various shades to suit the artist, by adding to the solution of gold a small quantity of the cyanides of silver, copper, or zinc, and a few drops of the hydro-sulphuret of ammonia."

ELECTRO-PLATING BATH. See CYANIDES.

ELECTRO-SORTING APPARATUS. — M. Froment has devised an apparatus for the separation of iron from matters by which it may be accompanied. The apparatus consists of a wheel carrying on its circumference eighteen electro-magnets. The iron ore reduced and pulverised is spread continually upon one of the extremities of a cloth drawn along with it, and passed under the electro-magnets in motion. The iron in the ore which has of course been brought into a magnetic state by any of the processes by which this may be effected, is separated by the magnets, and the impurities carried onward. See *De la Rive's Electricity.*

ELECTRO-TELEGRAPHY. The simultaneous appearance of the electric spark at the respective ends of a long conducting wire forcibly arrested the attention of electricians in the early days of the science.

A series of remarkable experiments were made by Dr. Watson, commencing on July 14th, 1747; when he passed an electric discharge from the Thames bank at Westminster to the opposite bank at Lambeth, by means of a wire suspended to Westminster Bridge. He continued his researches; and, on August the 5th of the following year, he arranged 12,276 feet of wire at Shooter's Hill, the beginning, the middle, and the end of which were led into the same apartment. He found out that the electric signs at the middle of the wire coincided in time with the discharge at the two ends, proving that the passage, at least in such a length of wire, was instantaneous. In reference to these results Professor Muschenbrock wrote to Dr. Watson; "Magnificentissimis tuis experimentis, superasti conatus omnium."

The idea of applying this property to the transmission afar of telegraph signals proper was an early and natural result of these discoveries. But many onward steps were necessary before the idea could assume any definite form; and further advances in knowledge were essential before the idea could be realised.

It would far exceed our limits were we to attempt the most hurried sketch of the history of this art; we shall therefore content ourselves with illustrating the leading doctrines, that have been realised in the telegraph systems which are most in favour at the time in which we write.

Locked up, as it were, in all bodies, is a large store of electric force, the equilibrium of which is disturbed in a greater or less degree by a variety of causes, some extremely simple, others more complex; and, according as one or other cause is in operation,

the conditions under which the electric force is manifested vary; some conditions being very unfavourable, and others very favourable to the object in view.

Friction is a well known means of producing electric effects. Amber (in Greek *electron*) was the first substance on which they were noticed in a special manner, and hence the name. Light bodies, such as gold leaf, or feathers, are attracted by rubbed amber; the leaf gold is quickly repelled again, the feathers not so readily. In due course it was discovered that this difference of behaviour is due to the gold conducting electricity, and the feathers not so; the one allowing the force to diffuse itself about it, the other receiving and retaining it only in or near the points of contact; if the former property were universal it would be impossible to collect electricity; if the latter, it would be impossible to get rid of it. *Conduction* is well illustrated and turned to useful account in the iron and copper wires, by which distant telegraph stations are connected with each other; *insulation*, by the glass or porcelain articles with which the said conducting wires are suspended to the poles above ground, and by the gutta percha with which the subterranean or submarine wires are covered.

The rapidity with which electric force traverses conductors depends upon the circumstances under which the conductors are placed; in one case, as in that of wire suspended in the air, the electric force has little else to do than to travel onward and be discharged from the far end of the wire; in the other case, as in that of buried wire, it has to disturb the electric equilibrium of the gutta percha as it travels onward, and thus suffers considerable retardation. The greatest recorded velocity of a signal through a suspended copper telegraph wire is 1,752,800 miles per second, by M. Hipp; the lowest velocity through a buried copper wire, 750 miles per second by Faraday. Intermediate velocities are recorded, for which the nature of the wire or the conditions under which it was placed were different. Wheatstone found the velocity of electricity under different conditions from the above to be 288,000 miles per second. His wire was copper, and was wound on a frame. The electricity that was employed by Mr. Wheatstone in these experiments was obtained from the friction of glass against an amalgam of tin. The various velocities are due partly to the conditions under which the conducting wire is placed, and partly, no doubt, to the varied properties of electricity from various sources. And the very different methods of reading off the velocities in this and in other cases may have an influence over the respective values.

Electricity is obtained from other sources than friction with so much greater facility, and in forms so much more applicable and manageable for telegraphic purposes, that frictional electricity has not been applied in real practice. It must not, however, be passed over in this place, because one of the earliest telegraphs, perhaps the very first in which a long length of wire was actually used, was actuated by this form of electricity. In 1816 Mr. Ronalds established, in the grounds attached to his residence at Hammersmith, eight miles of wire suspended by silk to dry wood, besides 175 yards of buried wire in glass tubes embedded in pitch and enclosed in troughs of wood. He obtained his electricity from a common electrical machine, and his signals from the motion of light bodies, balls of elder pith, produced under circumstances analogous to those to which we have already referred. At the far end of his telegraph wire two pith balls were suspended close together. Electricity applied at the home end of the wire at once diffused itself throughout the conducting system, including the pair of light balls. Just as we have seen gold leaf recede after having approached rubbed amber, and acquired an electric charge; so the pith balls, each being charged with electricity, derived from the same source, recede from each other; and this in obedience to the fundamental laws of static electricity, for which we must refer readers to treatises on the subject. Here, then, we have one solitary signal. The manner in which Mr. Ronalds turned it into language was ingenious. He pressed time into his service, and by combining time and motion he obtained a language. He provided a clock movement at each station; the clocks were so regulated as to be synchronous in their movements; each of them carried, in lieu of a hand, a light disc, having the letters of the alphabet and other signals engraved on it. The disc was hidden by a screen, in which was *one* opening. It is obvious that if the clocks were started together, and had uniform rates, the same letter at the same time would be visible through the opening in each screen; and letter by letter would pass seriatim and simultaneously before the respective openings. If absolute uniformity is difficult for long periods, it is practicable for shorter. The sender of a message watched the opening of his screen; the moment the letter approached that he desired to telegraph he charged the wire with electricity, and the balls at the far station moved; the letter then visible there corresponded with the one at the home station, and was read off. The sender watched till the next letter he required came round, and so on.

Let us now pass on to some of the leading features of electro-telegraphy, as it has

been realised of late years, and to a description of some of the telegraph instruments that are most in use.

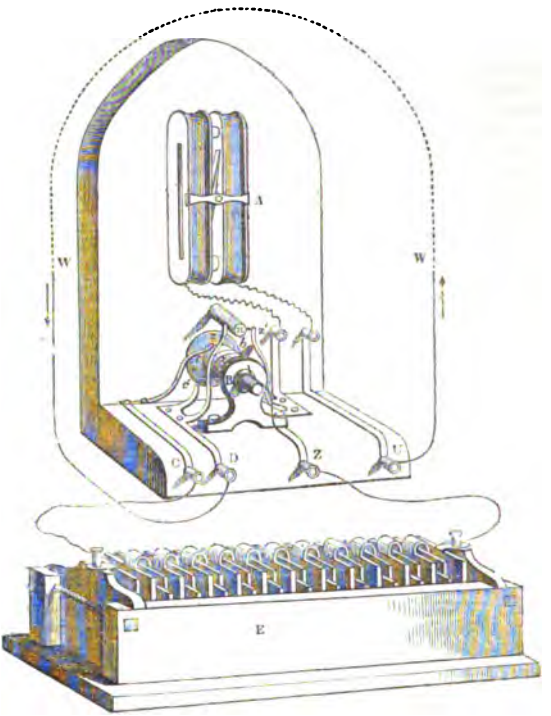
Chemical action is the most fertile source of electricity. If a silver fork and a steel knife are connected together by a piece of wire, and the fork is thrust into a piece of meat, say a hot mutton chop, the moment an incision is made in the meat with the knife, electricity will pass along the wire, and continue to do so while the above disposition of things remains. Upon the proper test being applied, the electricity is readily detected. This is the *current form* of electricity. The amount of force in circulation in this particular combination is not very great, and its power of travelling to a distance is not very high, but still it is quite capable of producing good, signals, on a delicate arrangement of the needle instrument (of which more hereafter) with which in England we are so familiar.

The amount of electricity obtained by means of chemical action, is increased to the required extent by a judicious selection of metals, and of the liquid or liquids in which they are immersed. Zinc is invariably used as one of the metals; it is represented by the iron of the knife in the above experiment. Copper, silver, and platinum or graphite (gas carbon) is selected for the other metal. When the two metals are immersed in a same liquid, a mixture of sulphuric acid with salt-water, or fresh, is employed. When two liquids are used, they are separated by a porous partition; the zinc is usually placed in the sulphuric acid solution, and the other metal in a solution varying with the nature of the arrangements proposed. Zinc is naturally soluble in the acid solution in question; and would therefore waste away and be consumed at the expense also of the acid, unless precautions were taken to make it resist the ordinary action of the solvent. When zinc is dissolved in mercury it is not attacked, under ordinary circumstances, by sulphuric acid solution. Hence the plates of zinc employed in all good voltaic combinations, as they are called, into which this acid, in a free state, enters, are protected by being well amalgamated, that is, they are dipped in a strong acid mixture and well washed; and are then dipped into a mercury bath, and are placed aside to drain. The operation is generally repeated a second time; and, in the best arrangements, the further precaution is taken of standing the zinc plate, while in the acid water, in some loose mercury, placed either in the bottom of the containing vessel, or in a gutta percha cell: by the latter arrangement, mercury is economised. In single liquid arrangements, it is desirable to select a metal that is not attacked by the acid. Copper has been extensively used, and is very valuable; but it possesses the defect of being slowly attackable. The waste, however, that it suffers in itself from this cause, is of small moment compared with certain secondary results, which terminate in the consumption of the acid and the zinc, and the destruction of the functions of the apparatus. Gold or platinum are free from these defects, but are too costly. Silver, is to a great extent free from them, and has been much and successfully used, especially when platinised, that is, having its surface covered with finely divided powder of platinum. The corrosion from gas retorts, cut into plates, and similarly treated, forms with amalgamated zinc one of the cheapest and most effective combinations.

A single pair of plates, no matter what their character, is unable to produce a force that can overcome the resistance of a wire of any length, and produce an available result at a distant station; and hence a series of pairs are employed in the telegraphic arrangements. E (*fig.* 704) represents a common mode of arranging a series of pairs of plates. It consists of a wooden trough made water-tight, and divided into water-tight cells. The metals are connected in pairs by copper bands; each pair is placed astride over a partition, and all the zincs face one way. When the plates (copper-zinc) are placed in, and the cells are filled up with pure white sand, and the acid water poured in, we have the very portable battery that was originally used by Mr. Cooke, and is still much employed in England. When batteries of a higher class are employed, the cells are distinct pots or jars; and great precautions are taken to prevent any conducting communication existing between the neighbouring cells, save by means of the copper band. In the trough form there is a leakage and loss of force from cell to cell. The c or copper is the positive end of such a series, and the z or zinc, the negative; and both are in a condition to discharge, either each to the other, by means of a wire led from one to the other, or each to the earth, one by a wire leading to the earth at the place where the battery stands, and the other by a long wire (say a telegraph wire), leading to the earth at a distant place. The resistance to be overcome is, in the former case, less; and the current of force in circulation is proportionately greater. Under whatever circumstances a wire takes part in promoting the discharge of an apparatus of this kind, the whole of the said wire is in a condition to indicate the presence of the force that is pervading it; and as the force may be presented to the wire in either of two directions, that is to say, the copper or the zinc, namely, the positive or the negative end of the battery, may be presented to the given end of the

telegraph wire, the relative condition of the wire will be modified accordingly. Not only can the direction of this current force be inverted at pleasure, but it can be maintained for any length of time, great or small, and in either direction. This is accomplished by various mechanical arrangements, which are the keys, commutators, or handles of the various telegraph instruments (of which more hereafter), and are often the only part presenting any complexity about them. In *fig.* 704, the source of electricity, E, we have already described; the test-instrument for the abnormal state of the wire, that is to say, the telegraph proper, is the part A. The complex part, consisting of springs, cylinders, and studs, shown below A, is nothing more than the necessary mechanical arrangement for directing at pleasure the current from the battery E, in either direction through the wire, and through the part A. By following the letters in the order here given, the course of the current may be traced from its leaving, say the positive or copper end of the battery, till its return to the zinc or negative end; C c′ D W W U A Z′ *b* B Z. If a companion instrument were in any part of the circuit of the wire W W, it would correspond in its signals with the home instrument, *fig.* 704.

704

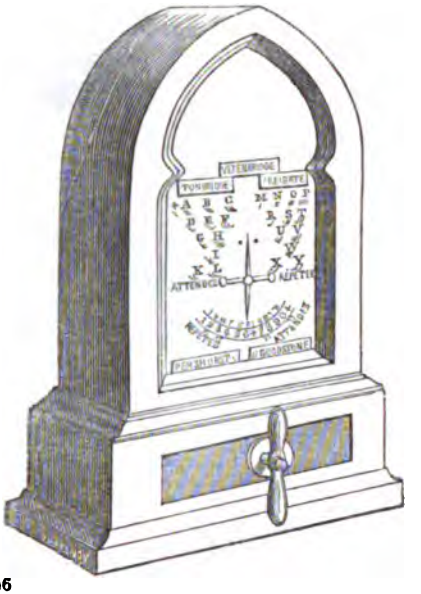


One of the properties possessed by a wire, during the c of discharging a voltaic battery, is to deflect a magnetised needle. If the two are parallel in the normal state of the wire, the needle is deflected this way or that, when the wire is in the abnormal state; and if the needle is very delicate, and a large enough amount of electricity is circulating through the wire, the needle reaches the maximum deflection of 90°. This is an extreme case, and cannot be approached in practice. Indeed, the deflection of any ordinary needle, under the action of an ordinary telegraph wire, would not be appreciable. But, as *every* foot of the wire has the *same* amount of reaction, we have merely so to arrange things that many feet,—a long length of the wire, shall be made to react upon the needle at the same time, and thus the effect is multiplied in proportion to the length of wire so concentrated. This is managed by covering a considerable quantity of fine wire with silk or cotton, and winding it on a frame A (*fig.* 704), suspending the needle within the frame. Such an instrument is called, from its properties, a *multiplier*. It is seen at a glance that the wire of the multiplier is an *addition* over and above the length of the actual telegraph wire required for reaching the distant station, and thus it practically increases the distance to be traversed: its smallness adds to this. The multipliers commonly used add a resistance equal to six or seven miles of telegraph wire.

Let us now turn to the face of the instrument. Here we have a dial and an index, which is on the same axis as the magnetised needle above described, capable of being deflected to the right *or* left, and limited in its motion by ivory pins. We have a handle for working the mechanical part so connected that, as it moves to the right, it directs a current into the wire such that the needle moves to the right, and *vice versâ*.

An alphabet is constructed from the combination of these two elementary motions, one or more of either or both kinds of deflection being used for the various letters, as shown on the engraved dial. This is Cooke and Wheatstone's single needle instrument, *fig.* 705.

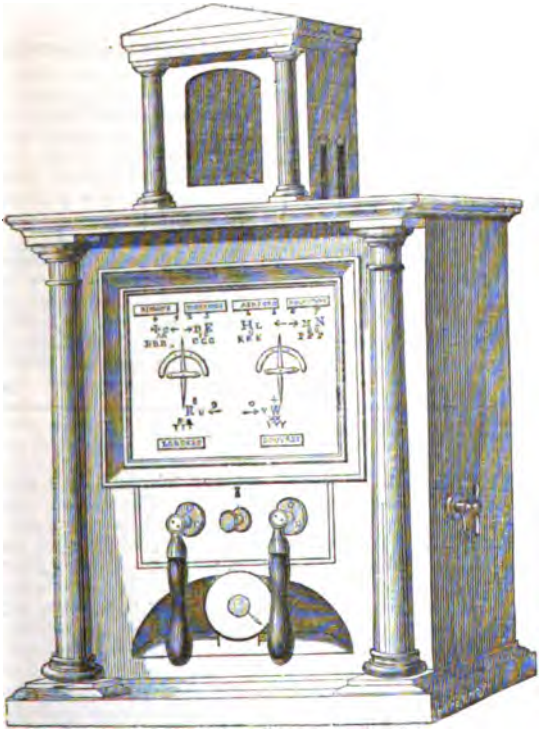
705



The form and character of their double needle instrument is shown in *fig.* 706. It is precisely a duplicate of the former; two handles, and their respective springs, studs, and cylinders, two multipliers, and two magnetised needles, with their external indexes, and two telegraph wires. One battery, however, is sufficient. One or more of either or both kinds of deflection of either or both needles, according to the code engraved on the dial, constitutes the alphabet. This instrument is very extensively employed; messages are sent by it with extreme rapidity.

Another property possessed by a wire conveying a current is that of converting soft iron, for the time, into a magnet. The attractive power, which can thus be given to, and withdrawn from, the soft iron at pleasure is turned to useful account, either in producing direct mechanical action, or in liberating the detents of a clock movement. Here also the effect of the

706



solitary wire is inappreciable, and many convolutions around the iron are necessary in order to obtain a useful result.

The simplest application of this principle is shown in *fig* 707. Here are two brass reels, filled with cotton-covered copper wire in one length. They are hollow, and a U-shaped bar of iron passes through them, presenting its ends at the face turned toward us in the drawing. This bar becomes magnetic, — forms what is called an *electro-magnet* every time and as long as an electrical current circulates in the wire; and its ends become respectively north and south poles. A narrow plate of iron, an *armature*, as it is termed, is mounted on pivots in front of the ends or poles of the magnet; it carries a vertical stem upon which the hammer is fixed. Every time the iron bar is magnetic the armature is attracted, and the hammer strikes the bell. The spring or contact-maker for introducing the current of electricity into the circuit, is shown in front on the right hand side. This is Mr. Walker's bell for signalling railway trains from station to station. The language consists of one or more blows. One, two, and three blows are the signals for common purposes, half a dozen blows is the limit. The acknowledgment of a signal is its repetition. By a simple arrangement of an index, that moves in fellowship with the hammer, the eye, as well as the ear, may read the bell signals.

707

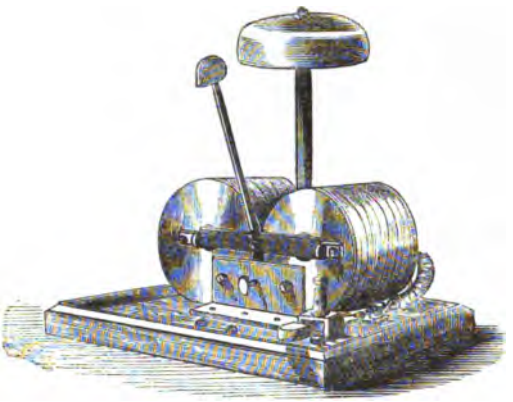
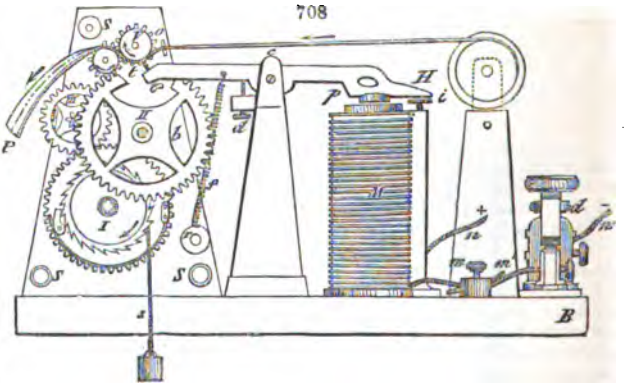


Fig. 708 shows another application of the direct action of an electro-magnet in pro-

708

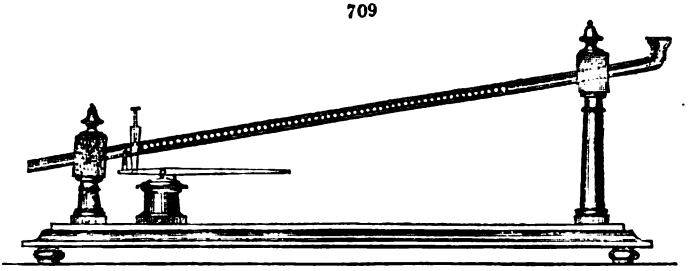


ducing telegraph signals. It is Morse's printing telegraph, very generally used in America, and used to no small extent in Europe. The coils of wire are shown at M, the armature at H, fixed at one end of the lever *p*, which is itself carried on centres at *c*. The range of motion here is small in order to produce rapid utterance; it is regulated by the screws *d* and *i*. The reaction of the spiral spring *f* restores the lever to its normal position each time the magnetism ceases. The signals consist of dots or dashes, variously combined, made by the pointed screw *t* upon the slip of paper *p*, running from the drum at the right in the direction of the arrows; a few such signals are shown upon the end of the paper slip. We have described the telegraph proper, which is seen to be extremely simple. The only parts at all complex are, as with the needle instruments already described, the mechanical parts, namely the train of wheels for carrying on the paper band, and the key or contact-maker, not shown in the figure. The amount of pressure required from the point *t* in order to produce a

mark, is such that it cannot conveniently be produced by the magnetic attraction, derived from a current of electricity that has come from a far distant station in order to circulate in the coils of wire M. This difficulty does not prevail in the signal-bells *fig.* 707, which are, at most, not required to be more than eight or ten miles apart, and in which also momentum can be and is accumulated so as to conspire in producing the final result. Morse has, therefore, had recourse to a *relay*, as he calls it. This, in principle, is pretty much the same thing as the instrument itself; but it has no heavy work to do, no marks to make; it has merely to act the part of a contact-maker or key; it can hence be made very delicate, so as to act well by such currents as would not produce any motion in the instrument itself. The batteries which furnish the electricity for doing the actual printing work in Morse's telegraph, are in the same station with the instrument itself. The office of the relay is to receive the signals from afar, and to make the necessary connections with the local battery and instrument so as to print off the signals on the paper in the usual way. It is obvious that the motions of the instrument and the relay are sympathetic, and that what a trained eye can read off from the one a trained ear can read off from the other. The relays are constructed with much finer wire than is required for the instrument itself, so that the current circulating in them, although very low in force, is multiplied by a very high number, and becomes equal to the delicate duty required of it.

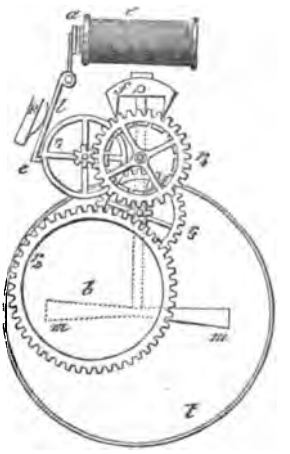
Fig. 709 is another illustration of the direct application of the electro-magnet without

709



adventitious aid. It represents a detent of McCallum's Globotype for recording signals. The long tube contains small glass balls, which are retained therein by a detent attached to the armature of an electro-magnet. Every time the armature is attracted *one* ball is liberated and runs down into a grooved dial, where it remains for inspection. One or more tubes and detents are used, according to the nature of the signal required, As applied to the signal bell (*fig.* 707) three tubes are used; one charged with black balls, for indicating the number of bell strokes made; one with white balls, for indicating the bell signals sent; one with spotted balls, for marking off the time in quarters of hours or intervals of less length. The balls, when liberated, all run into the same dial and arrange themselves seriatim.

710

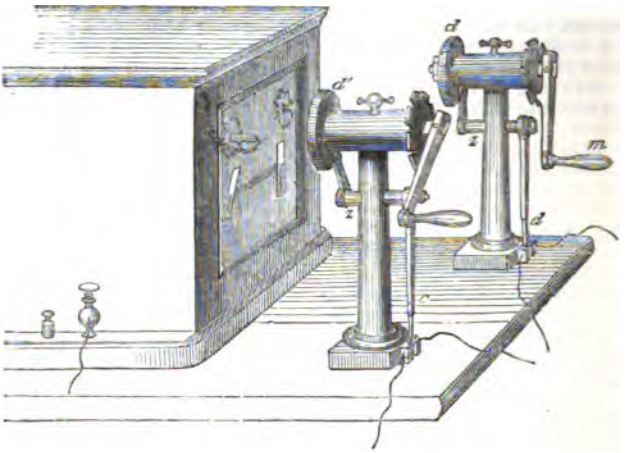


We may here refer to the case of another bell or alarum, in which the magnetic attraction derived from the current that arrives, is not equal to the mechanical work of striking a blow and sounding a bell; but which is able to raise a detent, that had restrained a train of wheels; and so allow the mechanism of the latter to do the work required. This arrangement is shown in Cooke and Wheatstone's alarum, *fig.* 710; *t* is the bell; *m m*, is the double headed hammer, which is in fact the pendulum, attached to the pallets *f*, which work in a scape-wheel hidden in the figure, and in gear in the usual way with a coiled spring in the box *b*, by the train r_4, r_1, r_3, r_2. The electro-magnetic part here, as in other instruments, is simple enough; *a c* is a lever moving on a centre above *l*, having at one end an armature *a*, facing the poles of the electro-magnet *e*; and at the other end *c*, a hook which faces the wheel *r*, and by catching in a notch on its circumference, keeps the train at rest. But when a current circulates through the coils *e*, the armature is attracted, the hook is raised, the train is liberated, and the pendulum-hammer vibrates and strikes a succession of blows. B is a support carrying a small spring, which reacts on the lever, and restores

it to its normal position when the magnetism ceases. This alarum is used for calling the attention of telegraph clerks. It requires a little attention to keep up the proper adjustment between the spring on the one hand, and the magnetic attraction on the other.

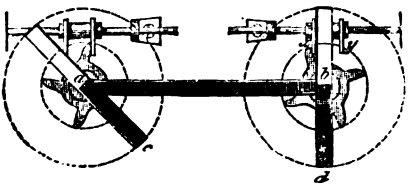
The telegraph originally adopted and still largely used by the French Administration, is somewhat akin to the alarum just described. It has a train of wheels, a scape-wheel with four teeth, and a pair of pallets. There is, however, no pendulum; but the pallets are connected with the armature of an electro-magnet, in such a manner that, for each attraction or repulsion of the armature, the scape-wheel is liberated half a tooth; for an attraction and a repulsion a whole tooth; so that four successive currents, producing of course four consecutive attractions and repulsions, produce a whole revolution of the scape-wheel. The axis of the latter projects through the dial of the instrument (*fig.* 711) and carries an arm *a* or *b* (*fig.* 712), which,

711



following the motion of the wheel, is able to assume eight distinct positions. The apparatus is generally double, as shown in the figure; and the signals are made up of the various combinations of the eight positions of each of the two arms. The arm is half black, the other half white. The position of the black portion is read off; the white portion is merely a counterpoise. When only one half of the dial, or one index is in use, the combinations are shown by producing with the one index successively the positions of the two, whose combination makes the signal, always giving first the position of the left hand index, then that of the right. The handles shown in front are the contact-makers; and are so constructed that the position of the arm on the dial coincides with the position given to the handle. *Fig.* 712 is a front view of the two arms; part of the dial is supposed to be removed, so as to expose the four-toothed-wheel already mentioned, and the pallets *x* and *z*; which, in their movement to and fro, allow of the semi-tooth advances of the wheel.

712



In these various applications of the electro-magnet, the armature has been of soft iron, and the only action of the electro-magnet has been to attract it. It has been withdrawn from the magnet after the electricity has ceased to circulate, either by its own gravity, by a counterpoise, or by a reacting spring. We now come to a telegraph that is well known and much used, Henley's magneto-electric telegraph, in which there is no reacting spring; and in which the movement or signal is produced by the joint action of attraction and repulsion; and the return to its normal state by the same joint action. Each pole of Henley's electro-magnet has a double instead of the single termination, that we have been considering in all preceding cases. A piece of soft iron, like a crescent, is screwed upon each of the poles; the horns or cusps of the respective crescents are facing and near to each other; and a magnetised steel needle is balanced between them. This arrangement is somewhat like the

following (|). So long as no current is circulating in the coils of the electro-magnet, the crescents are impassive soft iron, and no one point of either of them has more tendency than any other point to attract either end of the magnetised needle that is between them. But while a current is circulating, one of the crescents is endowed with north magnetic polarity, which is especially developed at its horns, and the other with south polarity. Suppose the horns of the right hand crescent are north poles, those of the left south poles, and the top end of the needle is north. Four forces will conspire to move the needle to the left. Its top will be attracted by the left hand crescent and repelled by the right; its bottom will be repelled by the left, and attracted by the right. When this current ceases to circulate, the simple attraction between the magnetised needle and the soft iron of the crescent tends to retain it in a deflected position. This tendency is increased by a little residual magnetism, that is apt to remain in the best iron, notwithstanding every care in its preparation. In order, therefore, to restore the needle to its normal position, a short quick current in the reverse direction is given. These instruments are single or double. Only one kind of deflection of the needle is available for actual signals; the other motion being merely the return to the normal state. The single needle alphabet is composed of deflections of a short or a long duration; these are produced by holding on the current for an instant or for more than an instant; and the various combinations of short and long correspond to Morse's dot and dash system. The double needle alphabet consists of combinations of the deflection of either or both needles.

Fig. 713 shows Henley's instrument, and, in completing the description of it, we have

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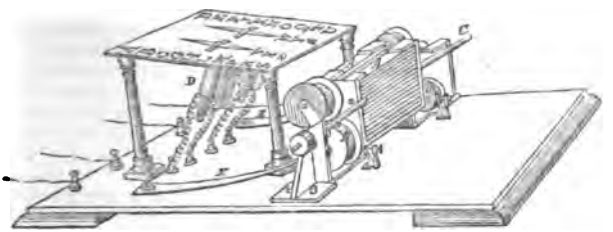

to describe another source of electric current to which no allusion has been hitherto made. The electricity here employed is obtained neither by friction nor by chemical action, but by means of magnetism *and* motion. If a piece of metal is moved in the presence of a magnet, or a magnet is moved in presence of a piece of metal, a current of electricity is generated in the metal. The results are multiplied when the metal is a coil of covered wire; so that we have here the converse of the electro-magnet; in the one case electricity had produced magnetism, in the other magnetism produces electricity; hence the name *magneto-electric* telegraph. We have here a powerful set of steel magnets A A, all the north ends pointing in one direction, and bound together with a plate of iron, and all the south ends similarly arranged in the other direction. Facing each end, but not quite in front when at rest, is an electro-magnet proper, B B, consisting of the U-shaped iron rod and the coil of covered wire, as described in *fig.* 707. Each electro-magnet is mounted upon an axis. C is a short lever or key; on depressing this the electro-magnet moves from its normal position in a region of lesser magnetic force, into a new position in the region of greatest magnetic force, and thus is the double condition, enunciated above, complied with; the copper wire is moved in the presence of a magnet, and this under the most favourable conditions; and the U iron, rising from a feeble to a strong magnet, its lines of magnetic force move in presence of the copper wire. Just as a current, *coming* from a long distance, had to be received in Morse's arrangement (*fig.* 708) in an electro-magnet of a long coil of fine wire, so as to be much multiplied in order to do its work, so here a magneto-electric current, that has to be *sent* to a long distance, must be generated in a long coil of very fine wire in order to have electro-motive force sufficient to overcome the resistance opposed to it. In like manner the electro-magnets of the instrument D, in which it is received at the far-off station, have the same multiplying characteristics. The magneto-electric current exists only during the motion of the electro-magnet in front of the steel magnets, and this motion must be rather brisk, or the change of place is slow and the current feeble; but the current ceases with the motion. The needle, however, remains deflected from causes to which we have already referred, and if the hand is raised gently, so that the coils return

slowly to their normal position, the needle will remain deflected ; but, if the hand is so removed that the coils return quickly from the region of greatest to one of lesser magnetic force, a reverse current of lesser force than the original is generated, which releases the needle from its deflected position and restores it to its normal place, ready for making the next signal. In a recent form of this instrument Mr. Henley has obviated the necessity of moving the electro-magnets, still retaining the same fundamental principles. He uses a set of large U-shaped permanent magnets, and places the electro-magnet in the space between the branches of the permanent magnet, and so that the four poles of the two magnets, the permanent and the electro, shall be flush with each other or in the same plane. A couple of iron armatures are mounted on a disc in front of the magnets. The disc has a motion on a centre ; the armatures are curved or crescent-shaped. Their form is so adjusted to the relative positions of the poles of the respective magnets that, in their normal or ordinary position, one crescent connects the N. pole of the magnet with one, say the *upper* pole of the electro-magnet, and the other crescent connects the S. pole of the permanent magnet with the *lower* pole of the electro-magnet. On pressing a key the disc moves, and the armatures so change in position that the N. pole of the magnet is connected with the *lower*, and the S. pole with the *upper* poles of the electro-magnet. By this arrangement the polarity of the electro-magnet is reversed at pleasure, and in its transition from being a magnet with poles in one direction, to becoming a magnet with poles in the reverse direction, an electric current is generated in the wire with which it is wound, and the direction of the current is this way or that according as the transition is from this direction of polarity to that. This form of magneto-electric machine allows of larger electro-magnetic coils being used, and gives the manipulator comparatively very little weight to move in signalling.

We have shown how an electric current generates magnetism, and how magnetism generates another electric current ; it would follow logically that one electric current should therefore generate another electric current ; for the magnetism produced by a current circulating in one wire, must have *all* the properties of magnetism, and among them, that of producing another current in another wire ; and so it is. A few convolutions of a large sized wire are coiled round an iron rod ; and outside the larger wire is a very great length of finer wire. The current from the battery is called the *primary* current in this arrangement ; and the moment it begins to circulate in the large wire, it magnetises the iron and generates a current, called *secondary*, in the fine wire, which is able to penetrate to a very great distance. When the primary current ceases, magnetisation ceases, the lines of magnetic force disappear, and a reverse secondary current is produced. This was the method proposed for obtaining the secondary current for traversing the Atlantic Ocean from Ireland to Newfoundland. The large wire is not necessarily first coiled on ; in the coils for the Transatlantic telegraph it was coiled outside. Nor is the presence of iron essential to obtaining secondary currents.

It will have been noticed in all the arrangements which have hitherto been described, that the signals are produced by motions,—that the electric current on reaching the far station is multiplied by being directed through many convolutions of wire, and is made to act upon either a piece of soft iron or a piece of magnetised steel, and to move them, the motion being turned to account directly, or by the intervention of mechanism, We have yet another property of electricity, that has been very successfully applied to the production of telegraphic signals by Mr. Bain, in his electro-chemical telegraph. If a current of electricity is led into a compound fluid body, say into water by one wire and out of it by another wire, the body is decomposed into its constituent elements, one of which, the oxygen in the case in question, makes its appearance at one wire and the other—the hydrogen makes its appearance at the other wire. The same holds good with bodies of a more complex character in solution in water. The compound selected by Mr. Bain is cyanide of potassium. With a solution of this, he saturates a long ribbon of paper, similar to that employed in Morse's telegraph. He causes the paper B (*fig.* 714) to pass over a drum of brass R, between the metal of R and an iron point or stylus P. The electric current enters the apparatus by the point P, passes through the solution of cyanide of potassium, with which the paper B is saturated, and out by the spring P', which is in metallic contact with the drum R. Decomposition takes place and the well known cyanide of iron (Prussian blue) is formed at the point of contact

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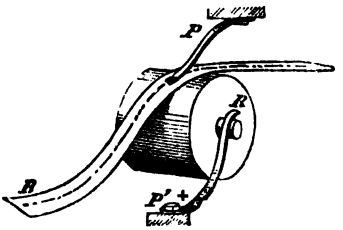

of the iron stylus P with the paper, the iron of the compound being supplied by the stylus itself. The paper is carried on by ordinary mechanism; and a dot and dash alphabet is formed, according to the duration of contacts at the sending station. There is a single wire and a double wire code; and the signals appear as deep blue marks upon the paper. Supplies of paper saturated with the solution are kept in reserve. This is unquestionably a telegraph of extreme simplicity. It has been employed with much success.

Mr. Whitehouse prepared for the Atlantic Telegraph a system in which motion and chemical action each play their part. The secondary currents that he employed were not able to produce the chemical decomposition that he requires for his signals. He therefore received them in a very sensitive relay, either an electro-magnet or a multiplier. The relay was a contact-maker, and connected the necessary number of local batteries with the printing apparatus, which consists of a ribbon of paper, saturated with a chemical solution and passing between a drum and a steel point.

We should exceed our limits, were we to attempt the description of some of the many other forms that have been proposed. The above are good illustrations of the leading principles, and are all in successful use. Some telegraphs will print in ordinary characters; this result is only attained by much complexity; and its value is more than questionable, it being as easy to learn a new code as a new alphabet; and telegraph clerks read their signals as readily as they read ordinary writing or printing, and they acquire their knowledge in a very short time. Hence probably it is that telegraphs to print in ordinary characters are but little known in real practice; nevertheless, some very promising instruments of the class have been produced, by House, and especially one more recently by Hughes, both of the United States. The following table has been drawn out as an illustration of the codes of some of the chief instruments that have been the subject of this article. It shows the number and nature of the signals (deflections, dots, dashes) for producing the name of the great discoverer of electro-magnetism, which is the foundation of electro-telegraph. The figures on the right are the number of marks or signs in printing and in each kind of telegraph.

		O	E	R	S	T	E	D	7
1. Single	Cooke and Wheatstone.	///	\\/	\/	\//	\///	\\/	\/	20
2. Double		// /	/	/ /	// //	/// ///	/	\/	18
3. Single	Henley	• • • •	•	— — —	— —	—	•	—. . .	16
4. Double		\///	//	\\ /	\\\ /	\ //	//	/	19
5. Morse		— —	•	• — •	• • •	—	•	— • •	15
6. Single	Bain	• •	•	— — •	— • •	— • — —	•	• • —	17
7. Double		— —	—	— —	— —	— — —	—	— —	16

The *Rheo-electro-static* system of telegraphy was first described by M. Botto, in 1848. It is applicable to some but not to all forms of telegraph. It has been applied on the South Eastern Railway to the signal-bells (*fig.* 704), for the purpose of reducing the amount of battery power required under other circumstances to be maintained. The wire, by which a pair of bells are connected, is in its normal state in permanent connection with the similar pole, say the positive, of batteries of equal power at the respective stations, so that two currents of equal power are opposed to and balanced against each other. Under these circumstances, the wire is in a null, or rheo-electro-static state; neither current circulates. If the connection of one of the batteries is reversed, so that its negative pole is presented to the wire, then the currents of both batteries are in the same direction, and they circulate as one current, equal in value to the combined force of the two batteries. The application is obvious; that, whereas, under the ordinary system, a *whole* battery, of force sufficient to traverse the distance and do effective work, must be at each station, under this system only *half* such battery is necessary at each station, for producing the same effective work. Also, if a little more battery power is placed at each station than is necessary for the actual work

required, signals of higher power are obtained under common circumstances; and also the equilibrium of the two opposed currents may be disturbed at any place between the two stations, and signals may be made by merely making a connection between the line-wire and the earth; because the negative pole at each station is fitted up in permanent connection with the earth; and, as the positive poles are in like connection with the line-wire, each battery current is made to circulate through its own signal-bell every time the earth and line-wire are placed in connection. By this means the guard of a train can make signals of distress to the nearest station without the aid of portable apparatus. Considerable care is required to obtain good communication with the earth on the open railway for making distress signals, or otherwise the discharge is imperfect, and no signal is made. Fish-jointed rails are very valuable for this purpose; in their absence, especially at embankments, metal must be buried for the purpose at intervals in the moist earth, and a wire attached for use. Contact springs on the telegraph poles are proposed.

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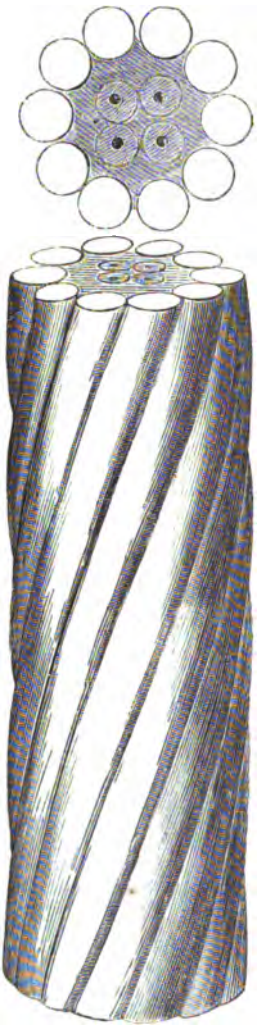

Telegraph wires are suspended to poles by insulators of earthenware, glass, or porcelain; the material and shape varying according to the experience of the engineer and the length of line to be insulated. In very short lengths, the battery power required for overcoming the resistance is not great; it will therefore not overcome the resistance of an insulator of moderate quality, and escape to the pole and thence to the earth; but the battery power required to overcome the resistance of very long lengths of wire is equally able to overcome the resistances presented by inferior insulators, and to escape in considerable quantities at every pole; so that the force which reaches the far station would not be equal to its work. It is for these long lines that the greatest ingenuity has been expended in constructing insulators. Fine porcelain is most in favour from its presenting a very smooth surface, and being less hygrometric than glass; and it is distorted into most mysterious looking shapes in order to present as great a distance, and one as much sheltered as possible, between the part, with which the line-wire is in contact, and the part that is in contact with the pole.

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For subterranean and submarine wires still greater care is necessary, because they are in the very bosom of the earth or sea, to which the current will escape, when and where it can, in order to complete the discharge. *Fig.* 715 represents the cable that has been lying in the British Channel between Dover and Calais, since September, 1851. It contains four No. 16 copper wires, each wire is doubly covered with gutta-percha. The four wires are then twisted into a rope; and the rope is thickly covered, first with hempen yarn, tarred, and finally with a jacket of ten No. 1 iron wires. The cable is shown in perspective and in section. *Fig.* 716 shows the perspective and section of the Irish, a single wire cable. It consists of a single central conductor, of one No. 16 copper wire, doubly covered with gutta percha, then with hempen yarn as before; and finally with a protecting jacket of ten No. 8 iron wires. The Calais cable weighs 7 tons per mile; the Irish, 2 tons per mile. The Atlantic

telegraph cable, of which nearly 3000 miles were prepared, is in section, just the size of a silver threepenny piece. It is a single wire cable, the wire was a strand of seven No. 22 copper wires, trebly covered with gutta percha, then with yarn, and protected with eighteen strands of seven wires each, of No. 22 iron wire. It weighs 19 cwt. to the mile. This cable is lost. The iron jacket is in disrepute now for deep sea cables. Hemp is preferred.

Telegraph signals pass with far less rapidity through buried and through submarine wires, than along the ancient aerial wires. The slow travellings mentioned above, were through wires of this kind. We must refer to treatises on Electricity for full details of the conditions presented by a telegraph cable. In practice it is found that on first sending a signal into a submerged wire, the electricity is delayed on its road, in order to produce a certain electrical condition upon the surface of the gutta percha that is in immediate contact with the conducting wire. Nor is this all; before a second distinctive signal can be sent, it is necessary that the condition produced by the first signal shall be destroyed; and this is an operation, requiring even more time than was consumed in the mere act of producing it. These two classes of retardation, especially the latter, were largely manifested in the Atlantic cable; and have called forth all the ingenuity of electricians, in order to mitigate or to modify them.—C. V. W.

ELECTRUM, or ELECTRON. The ancient Electrum was an alloy of gold with ⅕ part silver. The Electrum of Kalproth is gold 64 silver 36. The ancient name of amber. The modern Electrum is an alloy of copper, zinc, and tin, with sometimes nickel.

ELEMENTS. See EQUIVALENTS, CHEMICAL.

ELEMI. This appears to be the resinous product of various terebinthinous trees. The Edinburgh College, states it to be a "concrete resinous exudation from one or more unascertained plants." And the London Pharmacopœia describes it, as a concrete turpentine derived from an unknown plant. In the former edition *Amyris Elemifera* was named as the plant producing this resin. This error was due to Linnæus, who confounded under one name two distinct plants. The larger quantities of Elemi come to us from the Dutch settlements through Holland. It is imported in "*the lump*," and in masses weighing from one to two pounds each enveloped in a palm leaf.

Bonastre gives the constituents of Elemi:

Volatile oil	12·5
Resin soluble in hot and cold alcohol	60·0
Resin soluble in hot but not in cold alcohol	24·0
Bitter extractive	2·0
Impurities	1·5

The resin soluble in cold alcohol consists according to Johnston of $C^{40}H^{32}O^{4}$, while the latter (*Elimine*) is composed of $C^{40}H^{32}O$.

Elemi is employed in making lacquer. See VARNISH.

ELEUTRIATE. (*Soutirer*, Fr., *Schlemmen*, Germ.) When any insoluble powder such as chalk is diffused through a large body of water, and then allowed to subside slowly, of course the larger particles will by their gravity be the first to subside. If then the supernatant liquor is poured off, or better, if drawn off by a siphon, the finer powder will be collected in the next vessel; and by repeating this process an impalpable powder may be obtained. This process is called *Elutriation*.

ELEPHANTS' TUSKS. See IVORY.

ELIASITE. An ore of Uranium, a mineral allied to pitch blende, but differing from it widely in its large proportion of water and lower specific gravity (4·086 to 4·237).

It occurs with fluor, dolomite, quartz, &c., at the Elias mine, Joachimstal, in large flattened pieces, sometimes half an inch thick, of a dull reddish-brown colour, approaching to hyacinth-red on the edges.

It is subtranslucent, with a greasy subvitreous lustre, and affords a dull streak, varying from wax-yellow to orange. Hardness between calcite and fluor spar.

It is composed of	Peroxide of Uranium	61·33
„	Alumina	1·17
„	Peroxide of iron	6·63
„	Protoxide of iron	1·09
„	Lime	3·09
„	Magnesia	2·20
„	Oxide of lead	4·62
„	Silica	5·13
„	Carbonic acid	2·52
„	Phosphoric acid	0·84
„	Water	10·68
		99·30

Before the blowpipe it affords a reaction like pitchblende, Decomposed by muriatic acid.—H. W. B,

ELIXIR OF VITRIOL, a preparation of sulphuric acid, with some aromatics,

ELM. (*Ulmus. Orme*, Fr.; *Ulme*, Ger.) Of this European timber tree there are five species. The *Ulmus Campestris*, the English Elm, is regarded in this country as one of the finest of European deciduous trees for park scenery; it lives for upwards of 200 years, forming a remarkably straight tall trunk. The quality of timber depends a good deal on the soil in which it is grown, being always best on a dry, loamy soil, and plenty of air. The *Ulmus montana*, the Mountain-Scots or Wych Elm: the trunk is not so lofty nor the wood so heavy as the English Elm; and though coarse grained is very highly prized by shipbuilders and cartwrights. It possesses great longitudinal adhesion, and is consequently one of our stiffest and straightest timbers. These woods are not liable to split, and bear the driving of nails or bolts better than any other timber, and are exceedingly durable when constantly wet. They are therefore much used for the keels of vessels, and for wet foundations, waterworks, piles, pumps, and boards for coffins. On account of its toughness it is selected for the naves of wheels, and for the gunwales of ships.

ELVANS. Granitic and felspathic prophyritic rocks, which are frequently found traversing both the granite and slate rocks.

"The Elvans or veins of quartziferous porphyry, that is, a granular crystalline mixture of feldspar and quarts which are common both in Cornwall and Devon, and near the granite of the south-east of Ireland, are probably in reality granite veins, or veins proceeding from a granitic mass."—*Jukes.*

"When these *granite-veins* are of a large size they are termed *Elvan courses*; indeed this is the only distinction between these two forms of elongated masses of granitic rock. In composition these elvans are either shorl-rock, eurite, felsparite, or even varieties of fine-grained granite."—*Boase.*

EMAIL OMBRANT, a process which consists in flooding coloured but transparent glazes over designs stamped in the body of earthenware or porcelain. A plane surface is thus produced, in which the cavities of the stamped design appear as shadows of various depths, the parts in highest relief coming nearest the surface of the glaze, and thus having the effect of the lights of the picture. This process was introduced by the Baron A. De Tremblay of Rubelles, near Melun.

EMBALMING. (*Embaumement*, Fr.; *Embalsomen*, Germ.) An operation employed by the ancients to preserve human bodies from putrefaction. From their using *balsams* in the process, the name was derived. See DISINFECTION, PUTREFACTION.

EMBOSSING. One of the plans introduced for EMBOSSING CLOTH by machinery which appears to be the most effective, is that of Mr. Thomas Greig, of Rose Bank, near Bury. This machine is thus constructed.

Figs. 717, 718 represent three distinct printing cylinders of copper, or other suitable material A, B, C, with their necessary appendages for printing three different colours upon the fabric as it passes through the machine; either of these cylinders A, B, or C, may be employed as an embossing cylinder, without performing the printing process, or may be made to effect both operations at the same time.

The fabric or goods to be operated upon being first wound tightly upon a roller, that roller is to be mounted upon an axle or pivot, bearing in arms or brackets at the back of the machine, as shown at D. From this roller the fabric *a a a a* is conducted between tension rails, and passed under the bed cylinder or paper bowl E, and from thence proceeds over a carrier roller F, and over steam boxes not shown in the drawing, or it may be conducted into a hot room, for the purpose of drying the colours.

The cylinders A, B, and C, having either engraved or raised surfaces, are connected to feeding rollers *b*, *b*, *b*, revolving in the ink or coloured troughs *c*, *c*, *c*; or endless felts, called sieves, may be employed, as in ordinary printing machines, for supplying the colour, when the device on the surface of the cylinders is raised; these cylinders, may be furnished with doctors or scrapers when required, or the same may be applied to endless felts.

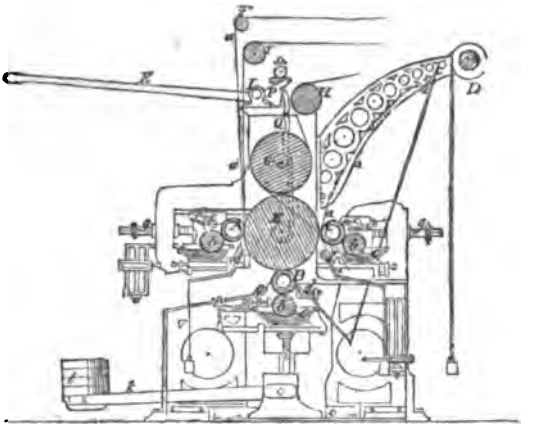
The blocks have adjustable screws *g*, *g*, for the purpose of bringing the cylinders up against the paper bowl with any required degree of pressure; the cylinder B is supported by its gudgeons running in blocks, which blocks slide in the lower parts of the side frames, and are connected to perpendicular rods *i*, having adjustable, screw nuts.

The lower parts of these rods bear upon weighed levers *k*, *k*, extending in front of the machine; and by increasing the weights *l*, *l*, any degree of upward pressure may be given to the cylinder B.

The colour boxes or troughs *c*, *c*, *c*, carrying the feeding rollers *b*, *b*, *b*, are fixed on boards which slide in grooves in the side frames, and the rollers are adjusted and brought into contact with the surface of the printing cylinders by screws.

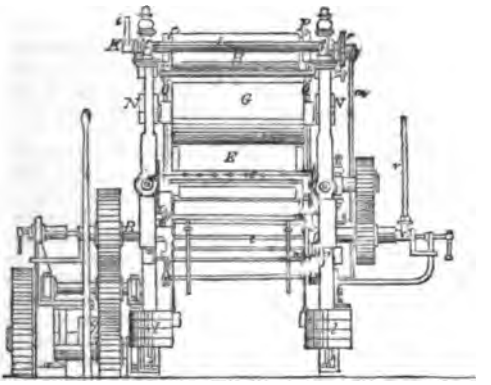
If a black cloth should be required to be introduced between the cylindrical bed or paper bowl E, and the fabric *a a a*, as the ordinary felt or blanket, it may, for printing and embossing cotton, silk, or paper, be of linen or cotton; but if woollen goods are to be operated upon, a cap of felt, or some such material, must be bound round the paper bowl, and the felt or blanket must be used for the back cloth, which is to be conducted over the rollers H and L.

717



For the purpose of embossing the fabric, either of the rollers A, B, or C, may be employed, observing that the surface of the roller must be cut, so as to leave the pattern or device elevated for embossing velvets, plain cloths, and papers; but for woollens the device must be excavated, that is, cut in recess.

718



The pattern of the embossing cylinder will, by the operation, be partially marked through the fabric on to the surface of the paper bowl E; to obliterate which marks from the surface of the bowl, as it revolves, the iron cylinder roller G is employed; but as in the embossing of the same patterns on paper, a counter roller is required to produce the pattern perfectly, the iron roller is in that case dispensed with, the impression given to the paper bowl being required to be retained on its surface until the operation is finished.

In this case the relative circumferences of the embossing cylinder, and of the paper bowl, must be exactly proportioned to each other; that is, the circumference of the bowl must be equal, exactly, to a given number of circumferences of the embossing cylinder, very accurately measured in order to preserve a perfect register or coincidence, as they continue revolving between the pattern on the surface of the embossing cylinder and that indented into the surface of the paper bowl.

The axle of the paper bowl E, turns in brasses fitted into slots in the side frames, and it may be raised by hand from its bearings, when required, by a lever *k*, extending in front. This lever is affixed to the end of a horizontal shaft L, L, crossing the machine seen in the figures, at the back of which shaft there are two segment levers P. P, to which bent rods Q, Q, are attached, having hooks at their lower ends, passed under the axle of the bowl. At the reverse end of the shaft L, a ratchet-wheel *r*, is affixed, and a pall or click mounted on the side of the frame takes into the teeth of the wheel *r*, and thereby holds up the paper bowl when required.

When the iron roller G, is to be brought into operation, the vertical screws *t*, *t*, mounted in the upper parts of the side frames, are turned, in order to bring down the brasses N, which carry the axle of that roller and slide in slots in the side frames.

The cylinders A, B, and C, are represented hollow, and may be kept at any desired temperature during the operation of printing, by introducing steam into them; and under the colour boxes *c*, *c*, *c*, hollow chambers are also made for the same purpose. The degree of temperature required to be given to these must depend upon the nature

of the colouring material, and of the goods operated upon. For the purpose of conducting steam to these hollow cylinders and colour boxes, pipes, as shown at *v*, *v*, *v*, are attached, which lead from a steam boiler. But when either of these cylinders is employed for embossing alone, or for embossing and printing at the same time, and particularly for some kinds of goods where a higher temperature may be required, a red-hot heater is then introduced into the hollow cylinder in place of steam.

If the cylinder B, is employed as the embossing cylinder, and it is not intended to print the fabric by that cylinder simultaneously with the operation of embossing, the feeding roller *b*, must be removed, and also the colour box *c*, belonging to that cylinder; and the cylinders A and C are to be employed for printing the fabric, the one applying the colour before the embossing is effected, the other after it. It is however to be remarked, that if A and C are to print colours on the fabric, and B to emboss it, in that case it is preferred, where the pattern would allow it. A and C are wooden rollers having the pattern upon their surfaces, and not metal, as the embossing cylinders must of necessity be.

It will be perceived that this machine will print one, two, or three colours at the same time, and that the operation of embossing may be performed simultaneously with the printing, by either of the cylinders A, B, or C, or the operation may be performed consecutively by the cylinders, either preceding or succeeding each other.

The situations of the doctors, when required to be used for removing any superfluous colour from the surface of the printing cylinder, are shown at *d*, *d*, *d*; those for removing any lint which may attach itself, at *e*, *e*, *e*. They are kept in their bearings by weighted levers and screws, and receive a slight lateral movement to and fro, by means of the vertical rod *m*, which is connected at top to an eccentric, on the end of the axle of the roller H, and at its lower end to a horizontal rod mounted at the side of the frame; to this horizontal rod, arms are attached, which are connected to the respective doctors; and thus by the rotation of the eccentric, the doctors are made to slide laterally.

When the cylinders A, B, or C, are employed for embossing only, those doctors will not be required. The driving power is communicated to the machine from any first mover through the agency of the toothed gear, which gives rotatory motion to the cylinder B, and from thence to the other cylinders A, and C, by toothed gear shown in *fig.* 717.

EMBOSSING LEATHER. Beautiful ornaments in basso-relievo for decorating the exteriors or interiors of buildings, medallions, picture-frames, cabinet work, &c., have been recently made by the pressure of metallic blocks and dies by M. Claude Schroth. The dies are made of type metal, or of the fusible alloy with bismuth, called d'Arcets. The leather is beaten soft in water, then wrung, pressed, rolled, and fulled as it were, by working it with the hands till it becomes thicker and quite supple. In this state it is laid on the mould, and forced into all its cavities by means of a wooden, bone, or copper tool. In other cases, the embossing is performed by the force of a press. The leather, when it has become dry, is easily taken off the mould, however deeply it may be inserted into its crevices by virtue of its elasticity.

EMBOSSING WOOD. (*Bossage*, Fr.; *Erhabenes*, *Arbeit*, Germ.) Raised figures upon wood, such as are employed in picture-frames, and other articles of ornamental cabinet work, are usually produced by means of carving, or by casting the pattern in plaster of Paris, or other composition, and cementing, or otherwise fixing it on the surface of the wood. The former mode is expensive; the latter is inapplicable on many occasions. The invention of Mr. Streaker may be used either by itself, or in aid of carving, and depends on the fact, that if a depression be made by a blunt instrument on the surface of the wood, such depressed part will again rise to its original level by subsequent immersion in the water.

The wood to be ornamented having been first worked out to its proposed shape, is in a state to receive the drawing of the pattern; this being put on a blunt steel tool, or burnisher, or die, is to be applied successively to all those parts of the pattern intended to be in relief, and, at the same time, is to be driven very cautiously, without breaking the grain of the wood, till the depth of the depression is equal to the intended prominence of the figures. The ground is then to be reduced by planing or filing to the level of the depressed part; after which, the piece of wood being placed in water, either hot or cold, the part previously depressed will rise to its former height, and will then form an embossed pattern, which may be finished by the usual operations of carving. See CARVING BY MACHINERY.

Another process which may be regarded either as carving or embossing wood, is that patented by Messrs. A. S. Braithwaite and Co.

Oak, mahogany, rose-wood, horse-chestnut, or other wood, is steeped in water for about two hours; and the cast iron mould containing the device is heated to redness, or sometimes to a white heat, and applied against the wood, either by a handle, as a branding iron, by a lever press, or by a screw-press, according to circumstances; the

moulds are made by the iron-founder from plaster casts of the original models or carvings.

Had not the wood been saturated with water, it would be ignited, but until the moisture is evaporated, it is only charred; it gives off volumes of smoke, but no flame. After a short time the iron is returned to the furnace to be re-heated, the blackened wood is well rubbed with a hard brush to remove the charcoal powder, which being a bad conductor of heat, saves the wood from material discoloration; and before the reapplication of the heated iron, the wood is again soaked in water, but for a shorter time, as it now absorbs moisture with more facility.

The rotation of burning, brushing, and wetting is repeated ten or twenty times, or upwards, until in fact the wood fills every cavity in the mould, the process being materially influenced by the character and condition of the wood itself, and the degrees to which heat and moisture are applied. The water so far checks the destruction of the wood, or even its change of any kind, that the burned surface, simply cleaned by brushing, is often employed, as it may be left either of a very pale or deep brown, according to the tone of colour required, so as to match old carvings of any age; or a very little scraping removes the discoloured surface. Perforated carvings are burned upon thick blocks of wood, and cut off with the circular saw.

EMBROIDERING MACHINE. (*Machine à broder*, Fr.; *Steckmaschine*, Germ.) This art has been from the earliest times a handicraft employment, cultivated on account of its elegance by ladies of rank. But M. Heilman, of Mulhouse, invented a machine of a most ingenious kind, which enables a female to embroider any design with 80 or 140 needles as accurately and expeditiously as she formerly could do with one. A brief account of this remarkable invention will therefore be acceptable to many readers. It was first displayed at the national exposition of the products of industry in Paris for 1834. 130 needles were occupied in copying the same pattern with perfect regularity, all set in motion by one person.

Several of these machines are now mounted in France, Germany, and Switzerland, and, with some modifications, in Manchester, Glasgow, and Paisley.

The price of a machine having 130 needles, and of consequence 260 pincers or fingers and thumbs to lay hold of them, is 5000 francs, or 200*l.* sterling; and it is estimated to do daily the work of 15 expert hand embroiderers, employed upon the ordinary frame. It requires merely the labour of one grown-up person, and two assistant children. The operative must be well taught to use the machine, for he has many things to attend to: with the one hand he traces out, or rather follows the design with the point of the pantograph; with the other he turns a handle to plant and pull all the needles, which are seized by pincers and moved along by carriages, approaching to and receding from the web, rolling all the time along an iron railway; lastly, by means of two pedals, upon which he presses alternately with the one foot and the other, he opens the 130 pincers of the first carriage, which ought to give up the needles after planting them in the stuff, and he shuts with the same pressure the 130 pincers of the second carriage, which is to receive the needles, to draw them from the other side, and to bring them back again. The children have nothing else to do than to change the needles when all their threads are used, and to see that no needle misses its pincers.

This machine may be described under four heads: 1. the structure of the frame; 2. the disposition of the web; 3. the arrangement of the carriages; and 4. the construction of the pincers.

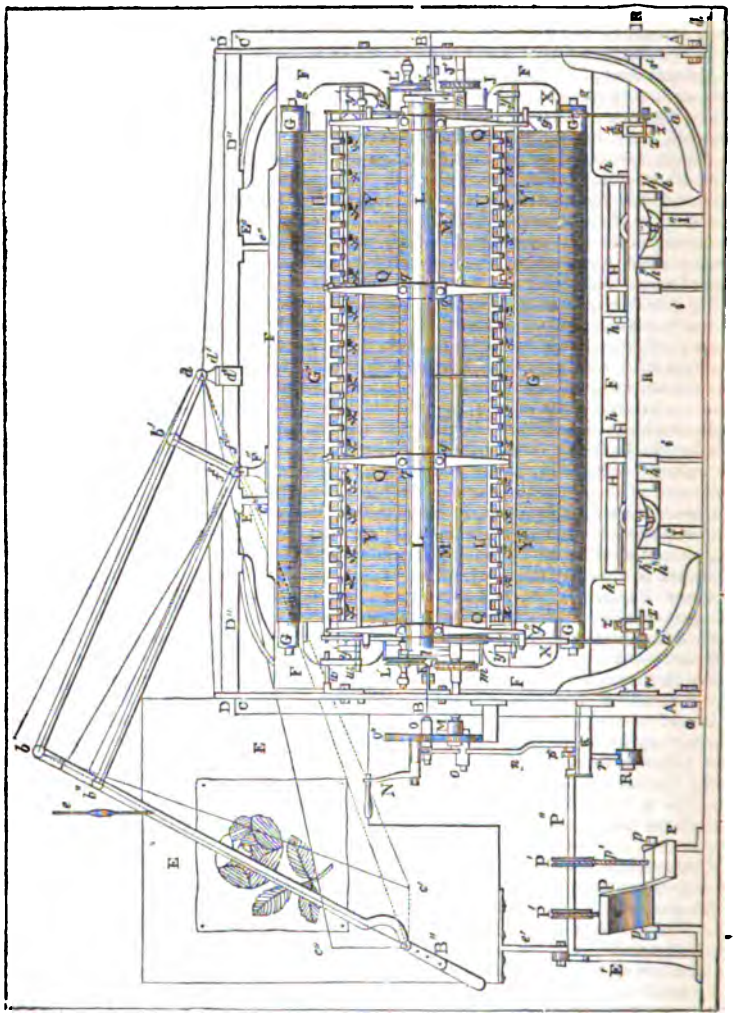
1. *The structure of the frame.*—It is composed of cast-iron, and is very massive. *Fig.* 719 exhibits a front elevation of it. The length of the machine depends upon the number of pincers to be worked. The model at the exposition had 260 pincers, and was 2 metres and a half (about 100 inches or 8 feet four inches English) long. The figure here given has been shortened considerably, but the other proportions are not disturbed. The breadth of the frame ought to be the same for every machine, whether it be long or short, for it is the breadth which determines the length of the thread to be put into the needles, and there is an advantage in giving it the full breadth of the model machine, fully 100 inches, so that the needles may carry a thread at least 40 inches long.

2. *Disposition of the piece to be embroidered.*—We have already stated that the pincers which hold the needles always present themselves opposite to the same point, and that in consequence they would continually pass backwards and forwards through the same hole, if the piece was not displaced with sufficient precision to bring successively opposite the tips of the needles every point upon which they are to work a design, such as a flower.

The piece is strained perpendicularly upon a large rectangular frame, whose four sides are visible in *fig.* 719; namely, the two vertical sides at F F, and the two horizontal sides, the upper and lower at F′ F″. We see also in the figure two long wooden

rollers G and G, whose ends, mounted with iron studs, are supported upon the sides F of the frame, so as turn to freely. These form a system of beams upon which the piece

719



destined to receive the embroidery, is wound and kept vertically stretched to a proper degree, for each of these beams bears upon its end a small ratchet wheel g, g; the teeth of one of them being inclined in the opposite direction to those of the other. Besides the system of lower beams, there is another of two upper beams, which is however but imperfectly seen in the figure, on account of the interference of other parts in this view of the machine. One of these systems presents the web to the inferior needles, and the other to the upper needles. As the two beams are not in the same vertical plane, the plane of the web would be presented obliquely to the needles were it not for a straight bar of iron, round whose edge the cloth passes, and which renders it vertical. The piece is kept in tension crosswise by small brass templets, to which the strings g'' are attached, and by which it is pulled towards the sides of the frame F. It remains to show by what ingenious means this frame may be shifted in every possible direction. M. Heilmann has employed for this purpose the pantograph which draughtsmen use for reducing or enlarging their plans in determinate proportions.

$b\ b'\ f''\ b''$ (*fig.* 719) represent a parallelogram, of which the four angles b, b', f'',

b'' are jointed in such a way that they may become very acute or very obtuse at pleasure, while the sides of course continue of the same length; the sides $b\ b'$ and $b\ b''$ are prolonged, the one to the point d, and the other to the point c, and these points c and d are chosen under the condition that in one of the positions of the parallelogram, the line $c\ d$ which joins them passes through the point f; this condition may be fulfilled in an infinite number of manners, since the position of the parallelogram remaining the same, we see that if we wished to shift the point d further from the point b', it would be sufficient to bring the point c near enough to b'', or *vice versâ*; but when we have once fixed upon the distance $b'\ d$, it is evident that the distance $b''\ c$ is its necessary consequence. Now the principle upon which the construction of the pantograph rests is this; it is sufficient that the three points d, f, and c be in a straight line, in one only of the positions of the parallelogram, in order that they shall remain always in a straight line in every position which can possibly be given to it.

We see in the figure that the side $b\ c$ has a handle B″ with which the workman puts the machine in action. To obtain more precision and solidity in work, the sides of the pantograph are joined, so that the middle of their thickness lies exactly in the vertical plane of the piece of goods, and that the axes of the joints are truly perpendicular to this plane, in which consequently all the displacements are effected. We arrive at this result by making fast to the superior great cross bar D″ an elbow piece d'', having a suitable projection, and to which is adapted in its turn the piece d', which receives in a socket the extremity of the side $b\ d$; this piece d' is made fast to d'' by a bolt, but it carries an oblong hole, and before screwing up the nut, we make the piece advance or recede, till the fulcrum point comes exactly into the plane of the web. This condition being fulfilled, we have merely to attach the frame to the angle f of the parallelogram, which is done by means of the piece F″.

It is now obvious that if the embroiderer takes the handle B″ in his hand and makes the pantograph move in any direction whatever, the point f will describe a figure similar to the figure described by the point c, and six times smaller, but the point f cannot move without the frame, and whatever is upon it moving also. Thus in the movement of the pantograph, every point of the web describes a figure equal to that described by the point f, and consequently similar to that described by the point c, but six times smaller; the embroidered object being produced upon the cloth in the position of that of the pattern. It is sufficient therefore to give the embroidering operative who holds the handle B″ a design six times greater than that to be executed by the machine, and to afford him at the same time a sure and easy means of tracing over with the point c, all the outlines of the pattern. For this purpose he adapts to c, perpendicularly to the plane of the parallelogram, a small style terminated by a point c', and he fixes the pattern upon a vertical tablet E, parallel to the plane of the stuff and the parallelogram, and distant from it only by the length of the style $c\ c''$; this tablet is carried by the iron rod e', which is secured to a cast iron foot E′, serving also for other purposes, as we shall presently see. The frame loaded with its beams and its cloth forms a pretty heavy mass, and as it must not swerve from its plane, it needs to be lightened, in order that the operative may cause the point of the pantograph to pass along the tablet without straining or uncertainty in its movements. M. Heilmann has accomplished these objects in the following way. A cord e attached to the side $b\ c$ of the pantograph passes over a return pulley, and carries at its extremity a weight which may be graduated at pleasure; this weight equipoises the pantograph, and tends slightly to raise the frame. The lower side of the frame carries two rods H and H, each attached by two arms $h\ h$, a little bent to the left; both of these are engaged in the grooves of a pulley. Through this mechanism a pressure can be exercised upon the frame from below upwards which may be regulated at pleasure, and without preventing the frame from moving in all directions, it hinders it from deviating from the primitive plane to which the pantograph was adjusted. The length of the rods H ought to be equal to the amount of the lateral movement of the frame. Two guides $i\ i$, carried by two legs of cast iron, present vertical slits in which the lower part of the frame F′ is engaged.

3. *Disposition of the carriages.*—The two carriages, which are similar, are placed the one to the right, and the other to the left of the frame. The carriage itself is composed merely of a long hollow cylinder of cast iron L, carrying at either end a system of two grooved castors or pulleys L′, which roll upon the horizontal rails K; the pulleys are mounted upon a forked piece l', with two ends to receive the axes of the pulleys, and the piece l' is itself bolted to a projecting car l cast upon the cylinder.

This assemblage constitutes, properly speaking, the carriage, resting in a perfectly stable equilibrium upon the rails K, upon which it may be most easily moved backwards and forwards, carrying its train of needles to be passed or drawn through the cloth.

M. Heilmann has contrived a mechanism by which the operative, without budging

from his place, may conduct the carriages, and regulate as he pleases the extent of their course, as well as the rapidity of their movements. By turning the axes M″ in the one direction or the other, the carriage may be made to approach to, or recede from, the web.

When one of the carriages has advanced to prick the needles into the stuff, the other is there to receive them; it lays hold of them with its pincers, pulls them through, performs its course by withdrawing to stretch the thread, and close the stitch, then it goes back with the needles to make its pricks in return. During these movements, the first carriage remains at its post waiting the return of the second. Thus the two chariots make in succession an advance and a return, but they never move together.

To effect these movements M. Heilmann has attached to the piece o′ made fast to the two uprights A C and A D of the frame, a bent lever *n o n′ n″*, movable round the point *o*; the bend *n′* carries a toothed wheel o′, and the extremity *n″* a toothed wheel o″; the four wheels M, M′, o′, and o″, have the same number of teeth and the same diameter; the two wheels o′ and o″ are fixed in reference to each other, so that it is sufficient to turn the handle N to make the wheel o″ revolve, and consequently the wheel o′; when the lever *n o* is vertical, the wheel o′ touches neither the wheel M nor the wheel M′; but if it be inclined to the one side or the other, it brings the wheel o′ alternately into gear with the wheel M or the wheel M′. As the operative has his two hands occupied, the one with the pantograph, and the other with the handle of impulsion, he has merely his feet for acting upon the lever *n o*, and as he has many other things to do, M. Heilmann has adapted before him a system of two pedals, by which he executes with his feet a series of operations no less delicate than those which he executes with his hands.

The pedals P are movable round the axis *p*, and carry cords *p′* wound in an opposite direction upon the pulleys P′; these pulleys are fixed upon a movable shaft P″ supported upon one side by the prop E′, and on the other in a piece K′ attached to the two great uprights of the frame. In depressing the pedal P (now raised in the figure), the upper part of the shaft P″ will turn from the left to the right, and the lever *n o* will become inclined so as to carry the wheel o′ upon the wheel M′, but at the same time the pedal which is now depressed will be raised, because its cord will be forced to wind itself upon its pulley, as much as the other cord has unwound itself; and thus the apparatus will be ready to act in the opposite direction when wanted.

4. *Disposition of the pincers.*—The shaft L′ carries, at regular intervals of a semi-diameter, the appendages *q q* cast upon it, upon which are fixed, by two bolts, the curved branches Q destined to bear the whole mechanism of the pincers. When the pincers are opened by their appropriate leverage, and the half of the needle, which is pointed at each end, with the eye in the middle, enters the opening of its plate, it gets lodged in an angular groove, which is less deep than the needle is thick, so that when the pincers are closed, the upper jaw presses it into the groove. In this way the needle is firmly held, although touched in only three points of its circumference.

Suppose now, that all the pincers are mounted and adjusted at their proper distances upon their prismatic bar, forming the upper range of the right carriage. For opening all the pincers there is a long plate of iron, U, capable of turning upon its axis, and which extends from the one end of the carriage to the other. This axis is carried by a kind of forks which are bolted to the extremity of the branches Q. By turning that axis the workman can open the pincers at pleasure, and they are again closed by springs. This movement is performed by his feet acting upon the pedals.

The threads get stretched in proportion as the carriage is run out, but as this tension has no elastic play, inconveniences might ensue, which are prevented by adapting to the carriage a mechanism by means of which all the threads are pressed at the same time by a weight susceptible of graduation. A little beneath the prismatic bar, which carries the pincers, we see in the figure a shaft Y, going from one end of the carriage to the other, and even a little beyond it; this shaft is carried by pieces *y* which are fixed to the arms Q, and in which it can turn. At its left end it carries two small bars *y′* and *w′*, and at its right a single bar *y′*, and a counterweight (not visible in this view); the ends of the two bars *y′* are joined by an iron wire, somewhat stout and perfectly straight. When the carriage approaches the web, and before the iron wire can touch it, the little bar *w* presses against a pin *w′*, which rests upon it, and tends to raise it more and more. In what has preceded we have kept in view only the upper range of pincers and needles, but there is an inferior range quite similar, as the figure shows, at the lower ends of the arms Q. In conclusion, it should be stated, that the operative does not follow slidingly with the pantograph the trace of the design which is upon the tablet or the picture, but he must stop the point of the style upon the point of the pattern into which the needle should enter, then remove it, and put it down again upon the point by which the needle ought to re-enter in coming from the other side of the piece, and so on in succession. To facilitate this kind of reading off, the pattern upon the tablet is composed of right lines terminated by the points for the entrance and

return of the needle, so that the operative (usually a child) has continually under her eyes the series of broken lines which must be followed by the pantograph. If she happens to quit this path an instant, without having left a mark of the point at which she had arrived, she is under the necessity of looking at the piece to see what has been already embroidered, and to find by this comparison the point at which she must resume her work, so as not to leave a blank, or to repeat the same stitch.

Explanation of Figure.

A, lower cross bars, which unite the legs of the two ends of the frame.
a, the six feet of the front end of the frame.
a', the six feet of the posterior end of the frame.
a'', curved pieces which unite the cross bars A'' to the uprights.
B'', handle of the pantograph.
b, *b'*, *b''*, three angles of the pantograph.
c, point of the side *b b''* on which the point is fixed.
C'', point of the pantograph.
D'', cross bar in form of a gutter, which unites the upper parts of the frame.
d, fixed point, round which the pantograph turns.
E, tablet upon which the pattern to be embroidered is put.
E', support of that tablet.
e, cord attached at one end to the side *b c* of the pantograph passing over a guide pulley, and carrying a weight at the other end.
e', iron rod by which the tablet E is joined to its support E'.
F, F, uprights of the cloth-carrying frame.
F', F', horizontal sides of the same frame.
G, four roll beams.
G'', the piece of cloth.
g'', the strings, which serve to stretch the cloth laterally.

This machine has not been applied for embroidering nets or muslins, as these fabrics are not sufficiently close to hold the needles; it has been hitherto used for embroidering cloth for vests and other purposes, and silk for ladies' dresses. We learn, however, that some very satisfactory experiments have been made by the Messrs. Houldsworth of Manchester, which promise shortly to lead to the successful application of these machines to the finer description of fabrics.

EMERY. This mineral was long regarded as an ore of iron; and was called by Haüy *fer oxidé quartzifère*. It is, however, a massive granular or compact variety of corundum, more or less impure. It is very abundant in the island of Naxos, at Cape *Emeri*, whence its name. From this place it is imported in large quantities. It occurs also in the islands of Jersey and Guernsey, at Almaden in Poland, Saxony, Sweden, Persia, &c. Its colour varies from red brown to dark brown; its specific gravity is about 4·000; it is so hard as to scratch quartz and many precious stones.

We have recent accounts of emery discoveries in Minnesota, but nearly all that is used at present in the arts comes from Turkey, near ancient Smyrna. Dr. Lawrence Smith, the American geologist, made a discovery of a deposit of emery while residing in Smyrna, and he made an examination of the locality in 1847. Dr. Smith having reported his discoveries to the Turkish government, a commission of inquiry was instituted, and the business soon assumed a mercantile form. The monopoly of the emery of Turkey was sold to a mercantile house in Smyrna, and since then the price has diminished in the market.

The following analyses are quoted by Dana from an elaborate paper by J. Lawrence Smith, in the *American Journal of Science*.

	Hardness, Sapphire being 100.	Specific Gravity.	Alumina.	Oxide of Iron.	Lime.	Silica.	Water.
Kulah - -	57	4·28	63·50	33·25	0·92	1·61	1·90
Samos - -	56	3·98	70·10	22·21	0·62	4·00	2·10
Nicaria - -	55	3·75	71·06	20·32	1·40	4·12	2·53
Kulah - -	53	4·02	63·00	30·12	0·50	2·36	3·36
Gumuch - -	47	3·82	77·82	8·62	1·80	8·13	3·11
Naxos - -	46	3·75	68·53	24·10	0·86	3·10	4·72
Nicaria - -	46	3·74	75·12	13·06	0·72	6·88	3·10
Gumuch - -	42	4·31	60·10	33·20	0·48	1·80	5·62
Kulah - -	40	3·89	61·05	27·15	1·30	9·63	2·00

The mining of the emery is of the simplest character. The natural decomposition of the rock in which it occurs facilitates its extraction. The rock decomposes into an

earth, in which the emery is found imbedded. The quantity procured under these circumstances is so great that it is rarely necessary to explore the rock. The earth in the neighbourhood of the block is almost always of a red colour, and serves as an indication to those who are in search of the mineral. Sometimes, before beginning to excavate, the spots are sounded by an iron rod with a steel point, and when any resistance is met with, the rod is rubbed in contact with the resisting body, and the effect produced on the point enables a practised eye to decide whether it has been done by emery or not. The blocks which are of a convenient size are transported in their natural state, but they are frequently broken by large hammers; when they resist the action of the hammer, they are subjected to the action of fire for several hours, and on cooling they most commonly yield to blows. It sometimes happens that large masses are abandoned, from the impossibility of breaking them into pieces of a convenient size, as the transportation, either on camels or horses, requires that the pieces shall not exceed 100 lbs. each in weight.

When reduced to a powder, emery varies in colour from dark grey to black. The colour of its powder affords no indication of its commercial value. The powder examined under the microscope shows the distinct existence of two minerals, corundum and oxide of iron. Emery, when moistened, always affords a very strong argillaceous odour. Its hardness is its most important property in its application to the arts, and was ascertained by Mr. Smith in the following manner:— Fragments were broken from the piece to be examined, and crushed in a diamond mortar with two or three blows of a hammer, then thrown into a sieve with 400 holes to the inch. The powder is then weighed, and the hardness tested with a circular piece of glass, about four inches in diameter, and a small agate mortar. The glass is first weighed, and placed on a piece of glazed paper; the pulverised emery is then thrown upon it at intervals, rubbing it against the glass with the bottom of the agate mortar. The emery is brushed off the glass from time to time with a feather, and when all the emery has been made to pass once over the glass, it is collected, and passed through the same operation three or four times. The glass is then weighed, again subjected to the same operation, the emery by this time being reduced to an impalpable powder. This series of operations is continued untill the loss sustained by the glass is exceedingly small. The total loss in the glass is then noted, and when all the specimens of emery are submitted to this operation under the same circumstances, an exact idea of their relative hardness is obtained. The advantages of using glass and agate are, that the latter is sufficiently hard to crush the emery, and in a certain space of time to reduce it to such an impalpable state, that it has no longer any sensible effect on the glass; and, on the other hand, the glass is soft enough to lose during this time sufficient of its substance to allow of accurate comparative results. By this method, the best emery was found capable of wearing away about half of its weight of common French window-glass.

In the ordinary process, the lumps of emery ore are broken up in the same manner as stone is for repairing macadamised roads, and into lumps of similar size. These lumps then crushed under stampers, such as are used for pounding metallic ores, driven by water or by steam power. It is supposed that the stampers leave the fragments more angular than they would be if they were ground under runners, a mode which is sometimes employed. The coarse powder is then sifted through sieves of wire cloth, which are generally cylindrical, like the bolting cylinders of corn-mills; but the sieves are covered with wire cloth, which vary from ninety to sixteen wires to the inch. No. 16 sieve gives emery of about the size of mustard-seed; and coarser fragments, extending nearly to the size of pepper-corns, are also occasionally prepared for the use of engineers. The sieves have sometimes as many as 120 wires in the inch; but the very fine sizes of emery are most commonly sifted through lawn sieves. The finest emery that is obtained from the manufacturers is that which floats in the atmosphere of the stamping-room, and is deposited on the beams and shelves, from which it is occasionally collected. The manufacturers rarely or never wash the emery; this is mostly done by the glass-workers, and such others as require a greater degree of precision than can be obtained by sifting.

The following table shows the number of wires usually contained in the sieves, and the names of the kinds respectively produced by them: —

	Wires.		Wires.
Corn emery	16	Coarse flour emery	60
Coarse grinding emery	24	Flour emery	70
Grinding emery	36	Fine flour emery	80
Fine grinding emery	46	Superfine flour emery	90
Superfine grinding emery	53		

Washing emery by hand is far too tedious for those who require very large quantities of emery, such as the manufacturers of plate glass and some others, who generally adopt the following method:—Twelve or more cylinders of sheet copper, of the common height of about two feet, and varying from about three, five, eight, to thirty or forty inches in diameter, are placed exactly level, and communicating at their upper edges, each to the next, by small troughs or channels; the largest vessel has also a waste-pipe near the top. At the commencement of the process, the cylinders are all filled to the brim with clean water; the pulverised emery is then churned up with abundance of water in another vessel, and allowed to run into the smallest or the three-inch cylinder, through a tube opposite the gutter leading to the second cylinder. The water during its short passage across the three-inch cylinder, deposits in that vessel such of the coarsest emery as will not bear suspension for that limited time; the particles next finer are deposited in the five-inch cylinder, during the somewhat longer time the mixed stream takes in passing the brim of that vessel; and so on. Eventually the water forms a very languid eddy in the largest cylinder, and deposits therein the very fine particles that have remained in suspension until this period; and the water, lastly, escapes by the waste-pipe nearly or entirely free from emery. In this simple arrangement, time is also the measure of the particles respectively deposited in the manufacture to which the emery is applied. When the vessels are to a certain degree filled with emery, the process is stopped, the vessels are emptied, the emery is carefully dried and laid by, and the process is recommenced.

Holtzapffel informs us that he has been in the habit, for many years, of employing emery of twelve degrees of fineness, prepared by himself by washing over.

For optical purposes, Mr. Ross mixes four pounds of the flour of emery of commerce, with one ounce of powdered gum-arabic, and then throws the powder into two gallons of clear water; and he collects the deposit at the end of 10″ and 30″, and 2′ 10′ 20′ and 60′, and that which is not deposited by one hour's subsidence is thrown away as useless for grinding lenses.

Emery paper is prepared by brushing the paper over with thin glue, and dusting the emery-powder over it from a sieve. There are about six degrees of coarseness. Sieves with thirty and ninety meshes per linear inch, are in general the coarsest and finest sizes employed. When used by artisans, the emery-paper is commonly wrapped round a file or a slip of wood, and applied just like a file, with or without oil, according to circumstances. The emery-paper cuts more smoothly with oil, but leaves the work dull.

Emery cloth only differs from emery-paper in the use of thin cotton cloth instead of paper, as the material upon which the emery is fixed by means of glue. The emery cloth, when folded around a file, does not ply so readily to it as emery-paper, and is apt to unroll. Hence smiths, engineers, and others, prefer emery-paper and emery-sticks; but for household and other purposes, where the hand alone is used, the greater durability of the cloth is advantageous.

Emery-sticks are rods of board about eight or twelve inches long, planed up square; or with one side rounded like a half round file. Nails are driven into each end of the stick as temporary handles; they are then brushed over one at a time with thin glue, and dabbed at all parts in a heap of emery powder, and knocked on one end to shake off the excess. Two coats of glue and emery are generally used. The emery-sticks are much more economical than emery-paper wrapped on a file, which is liable to be torn.

Emery-cake consists of emery mixed with a little beeswax, so as to constitute a solid lump, with which to dress the edges of buff and glaze wheels. The ingredients should be thoroughly incorporated by stirring the mixture whilst fluid, after which it is frequently poured into water, and thoroughly kneaded with the hands, and rolled into lumps before it has time to cool. The emery-cake is sometimes applied to the wheels whilst they are revolving; but the more usual course is, to stop the wheel and rub in the emery cake by hand. It is afterwards smoothed down by the thumb.

Emery-paper, or patent razor-strop paper, an article in which fine emery and glass are mixed with paper pulp, and made into sheets as in making ordinary paper; the emery and glass are said to constitute together 60 per cent. of the weight of the paper, which resembles drawing-paper, except that it has a delicate fawn colour. The emery-paper is directed to be pasted or glued upon a piece of wood, and when rubbed with a little oil, to be used as a razor-strop.

In 1842, Mr. Henry Barclay took out a patent for a method of combining powdered emery into *discs* and *laps* of different kinds, suitable to grinding, cutting, and polishing glass, enamels, metals, and other hard substances. The process of manufacture is as follows:—Coarse emery-powder is mixed with about half its weight of pulverised Stourbridge loam and a little water or other liquid, to make a

thick paste; this is pressed into a metallic mould by means of a screw-press, and after having been thoroughly dried, is baked or burned in a muffle or close receiver at a temperature considerably above a red heat and below the full white heat. In this case, the clay or alumina serves as a bond, and unites the particles very completely into a solid artificial emery-stone, which cuts very greedily, and yet seems hardly to suffer perceptible wear.

Superfine grinding emery is formed into wheels exactly in the same manner as the above, but the proportion of loam is then only one-fourth instead of one-half that of the emery. Those emery stones, which are of medium fineness, cut less quickly, but more smoothly than the above.

Flour-emery, when manufactured into artificial stones, requires no uniting substance, but the moistened powder is forced into the metal mould and fired; some portions of the alumina being sufficient to unite the whole. These fine wheels render the works submitted to them exceedingly smooth, but they do not produce a high polish on account of the comparative coarseness of the flour-emery.

The alumina of emery is believed to be aggregated to the same degree of hardness as in corundum or adamantine spar; which is one of the hardest minerals known. Emery is extensively employed for grinding metals, glass, &c.; for which purpose it is reduced to powders of different degrees of fineness by grinding and elutriation.

EMERALD (*Emeraude*, Fr.; *Smaragd*, Germ.), is a precious stone of a beautiful green colour; valued next to diamond, and in the same rank as oriental ruby and sapphire. It occurs in prisms with a regular hexagonal base; sp. grav. 2·7; scratches quartz with difficulty; is scratched by topaz; fusible at the blowpipe into a frothy bead; the precipitate afforded by ammonia, from its solution, is soluble, in a great measure, in carbonate of ammonia. Its analysis is given very variously by different chemists. It contains about 14 per cent. of glucina, which is its characteristic constituent, along with 68 of silica, 16 of alumina, a very little lime and iron. The beautiful emerald of Peru is found in a clay schist mixed with some calcareous matter. A stone of 4 grains weight is said to be worth from 4*l.* to 5*l.*; one of 8 grains, 10*l.*; one of 15 grains, being fine, is worth 60*l*; one of 24 grains fetched, at the sale of M. de Drée's cabinet, 2400 francs, or nearly 100*l.*

The beryl is analogous in composition to the emerald, and is employed (when of the common opaque kind, found near Limoges) by chemists for procuring the earth glucina.

Fine emeralds are found in a vein of dolomite, which traverses the hornblende slate at Muzo, north of Santa Fé de Bogota. A perfect hexagonal crystal from this locality, two inches long, is in the cabinet of the Duke of Devonshire; it measures across its three diameters 2¼ in., 2¼ in., 1⅞ in., and weighs 8 oz. 18 dwts:—owing to flaws, it is but partially fit for jewellery. A more splendid specimen, though somewhat smaller, weighing but 6 oz., is in the possession of Mr. Hope; it cost 500*l.* Emeralds of less beauty, but much larger, occur in Siberia. One specimen in the royal collection measures 14½ inches long and 12 broad, and weighs 16¾ lbs. troy; another is 7 inches long and 4 inches broad, and weighs 6 lbs. troy.—*Dana.*

The emerald is generally believed to derive its colour from the presence of a minute quantity of oxide of chrome, the beryl from oxide of iron.

This mineral has been recently examined with great care by M. Lewy, from whose communication to the Academy of Sciences we abstract the following:—

"M. Lewy visited a mine called Muzo, in New Granada, Mexico, and obtained some fine specimens of emeralds, and of the rocks in which those precious stones are found. He observed that the largest and finest emeralds could be reduced to powder by a slight squeezing or rubbing between the fingers when first obtained, but that they acquired hardness after a certain time and repose. It has been commonly stated that the colouring matter of the emerald is chrome, but M. Lewy attributes it to an organic colouring matter, analogous to *chlorophyle.* He states that the emerald exposed to heat loses all colour; whereas minerals coloured by chrome, do not lose their green colour by ignition. His analysis of the Mexican mineral is as follows:—

Silica - - - - - - -	67·9
Alumina - - - - - - -	17·9
Glucina - - - - - - -	12·4
Magnesia - - - - - - -	0·9
Soda - - - - - - -	0·7

The green colour of the emerald is darkest in those specimens which furnish to analysis most organic matter: it is completely destroyed by heat, becoming white and opaque.

EMETINE. A base constituting the emetic principle in ipecacuanha.—C. G. W.

EMPYREUMA, means the offensive smell produced by fire applied to organic matters, chiefly vegetable, in close vessels. Thus, empyreumatic vinegar is obtained by distilling wood at a red heat, and empyreumatic oil from many animal substances in the same way.

ENAMELS (*Emaux*, Fr.; *Schmelzglas*, Germ.) are varieties of glass, generally opaque or coloured, always formed by the combination of different metallic oxides, to which certain fixed fusible salts are added, such as the borates, fluates, and phosphates.

The simplest enamel, and the one which serves as a basis to most of the others, is obtained by calcining first of all a mixture of lead and tin, in proportions varying from 15 to 50 parts of tin for 100 of lead. The middle term appears to be the most suitable for the greater number of enamels; and this alloy has such an affinity for oxygen, that it may be calcined with the greatest ease in a flat cast-iron pot, and at a temperature not above a cherry red, provided the dose of tin is not too great. The oxide is drawn off to the sides of the melted metal, according as it is generated, new pieces of the alloy being thrown in from time to time, till enough of the powder be obtained. Great care ought to be taken that no metallic particles be left in the oxide, and that the calcining heat be as low as is barely sufficient; for a strong fire frits the powder, and obstructs its subsequent comminution. The powder when cold is ground in a proper mill, levigated with water, and elutriated. In this state of fineness and purity, it is called *calcine* or flux, and it is mixed with silicious sand and some alkaline matter or sea-salt. The most ordinary proportions are, 4 of sand, 1 of sea-salt, and 4 of *calcine*. Chaptal states, that he has obtained a very fine product from 100 parts of calcine, made by calcining equal parts of lead and tin, 100 parts of ground flint, and 200 parts of pure sub-carbonate of potash. In either case, the mixture is put into a crucible, or laid simply on a stratum of sand, quicklime spontaneously slacked, or wood-ashes, placed under a pottery or porcelain kiln. This mass undergoes a semivitrification, or even a complete fusion on its surface. It is this kind of frit which serves as a radical to almost every enamel; and by varying the proportions of the ingredient, more fusible, more opaque, or whiter enamels are obtained. The first of these qualities depends on the quantity of sand or flux, and the other two on that of the tin.

The sea-salt employed as a flux may be replaced either by salt of tartar, by pure potash, or by soda; but each of these fluxes gives peculiar qualities to the enamel.

Most authors who have written on the preparation of enamels, insist a great deal on the necessity of selecting carefully the particular sand that should enter into the composition of the frit, and they even affirm that the purest is not the most suitable. Clouet states, in the 34th volume of the *Annales de Chimie*, that the sand ought to contain at least 1 part of talc for 3 of silicious matter, otherwise the enamel obtained is never very glassy, and that some wrinkled spots from imperfect fusion are seen on its surface; and yet we find it prescribed in some old treatises, to make use of ground flints, fritted by means of salt of tartar or some other flux. It would thence appear that the presence of talc is of no use towards the fusibility of the silica, and that its absence may be supplied by increasing the dose of the flux. In all cases, however, we ought to beware of metallic oxides in the sand, particularly those of iron and manganese, which most frequently occur, and always injure the whiteness of the frit.

The ancients carried the art of enamelling to a very high perfection, and we occasionally find beautiful specimens of their work. Then, as at present, each artist made a mystery of the means that succeeded best with him, and thus a multitude of curious processes have been buried with their authors.

The Venetians are still in possession of the best enamel processes, and they supply the French and other nations with the best kinds of enamel, of every coloured shade.

Enamels are distinguished into transparent and opaque; in the former all the elements have experienced an equal degree of liquefaction, and are thus run into crystal glass, whilst in the others, some of their elements have resisted the action of heat, so that their particles prevent the transmission of light. This effect is produced particularly by the oxide of tin.

The frits for enamels that are to be applied to metallic surfaces require greater fusibility, and should therefore contain more flux; and the sand used for these should be calcined beforehand with one-fourth its weight of sea-salt; sometimes, indeed, metallic fluxes are added, as minium or litharge. For some metallic colours, the oxides of lead are very injurious, and in this case recourse must be had to other fluxes. Clouet states that he has derived advantage from the following mixtures, as bases for purples, blues, and some other delicate colours: —

Three parts of silicious sand, one of chalk, and three of calcined borax; or, three of glass (of broken crystal goblets), one of calcined borax, one-fourth of a part of nitre,

and one part of well-washed-diaphoretic antimony. These compositions afford a very white enamel, which accords perfectly well with blue.

It is obvious that the composition of this primary matter may be greatly varied: but we should never lose sight of the essential quality of a good enamel; which is, to acquire, at a moderate heat, sufficient fluidity to take a shining surface, without running too thin. It is not complete fusion which is wanted; but a pasty state, of such a degree as may give it, after cooling, the aspect of having suffered complete liquefaction.

Dead-white Enamel. — This requires greater nicety in the choice of its materials than any other enamel, as it must be free from every species of tint, and be perfectly white; hence the frit employed in this case should be itself composed of perfectly pure ingredients. But a frit should not be rejected hastily because it may be somewhat discoloured, since this may depend on two causes; either on some metallic oxides, or on fuliginous particles proceeding from vegetable or animal substances. Now the latter impurities may be easily removed by means of a small quantity of peroxide of manganese, which has the property of readily parting with a portion of its oxygen, and of thus facilitating the combustion, that is to say, the destruction of the colouring carbonaceous matter. Manganese indeed possesses a colouring power itself on glass, but only in its highest state of oxidisement, and when reduced to the lower state, as is done by combustible matters, it no longer communicates colour to the enamel combinations. Hence the proportion of manganese should never be in excess; for the surplus would cause colour. Sometimes, indeed, it becomes necessary to give a little manganese-colour, (i. e. a pink tint) in order to obtain a more agreeable shade of white; as a little azure blue is added to linens, to brighten or counteract the dulness of their yellow tint.

A white enamel may be conveniently prepared also with a *calcine* composed of two parts of tin and one of lead calcined together; of this combined oxide, one part is melted with two parts of fine crystal and a very little manganese, all previously ground together. When the fusion is complete, the vitreous matter is to be poured into clear water, and the frit is then dried, and melted anew. The pouring into water and fusion are sometimes repeated four times, in order to secure a very uniform combination. The crucible must be carefully screened from smoke and flame. The smallest portions of oxide of iron or copper admitted into this enamel will destroy its value.

Some practitioners recommend the use of washed diaphoretic antimony (antimoniate of potash, from metallic antimony, and nitre deflagrated together) for white enamel; but this product cannot be added to any preparation of lead or other metallic oxides; for it would tend rather to tarnish the colour than to clear it up; and it can be used therefore only with ordinary glass, or with saline fluxes. For three parts of white glass (without lead) one part of washed diaphoretic antimony is to be taken; the substances are well ground together, and fused in the common way.

Blue Enamel.—This fine colour is almost always obtained from the oxide of cobalt or some of its combinations, and it produces it with such intensity that only a very little can be used, lest the shade should pass into black. The cobalt blue is so rich and lively that it predominates in some measure over every other colour, and masks many so that they can hardly be perceived; it is also most easily obtained. To bring it out, however, in all its beauty, the other colours must be removed as much as possible, and the cobalt itself should be tolerably pure. This metal is associated in the best known ores with a considerable number of foreign substances, as iron, arsenic, copper, nickel, and sulphur, and it is difficult to separate them completely; but for enamel blues, the oxide of cobalt does not require to be perfectly free from all foreign metals; the iron, nickel, and copper being most prejudicial, should be carefully eliminated. This object may be most easily attained by dissolving the ore in nitric acid, evaporating this solution to a syrupy consistence, to expel the excess of acid, and separate a portion of arsenic. It is now diluted with water, and solution of carbonate of soda is dropped slowly into it with brisk agitation, till the precipitate, which is at first of a whitish gray, begins to turn of a rose-red. Whenever this colour appears, the whole must be thrown on a filter, and the liquid which passes through must be treated with more of the carbonate of soda, in order to obtain the arseniate of cobalt, which is nearly pure. Since arsenic acid and its derivatives are not capable of communicating colour themselves, and as they moreover are volatile, they cannot impair the beauty of the blue, and hence this preparation affords it in great perfection.

Metallic fluxes are not the most suitable for this colour; because they always communicate a tint of greater or less force, which never fails to injure the purity of the blue. Nitre is a useful addition, as it keeps the oxide at the maximum of oxidation, in which state it produces the richest colour.

Yellow Enamel.—There are many processes for making this colour in enamel; but it is somewhat difficult to fix, and it is rarely obtained of an uniform and fine tint. It may be produced directly with some preparations of silver, as the phosphate or sulphate; but this method does not always succeed, for too strong a heat or powerful fluxes readily destroy it, and nitre is particularly prejudicial. This uncertainty of success with the salts of silver causes them to be seldom employed; and oxides of lead and antimony are therefore preferred, which afford a fine yellow when combined with some oxides that are refractory enough to prevent their complete vitrification. One part of white oxide of antimony may be taken with from one to three parts of white lead, one of alum, and one of sal-ammoniac. Each of these substances is to be pulverised, and then all are to be exactly mixed, and exposed to a heat adequate to decompose the sal-ammoniac. This operation is judged to be finished when the yellow colour is well brought out. There is produced here a combination quite analogous to that known under the name of Naples yellow.

Other shades of yellow may be procured either with the oxide of lead alone, or by adding to it a little red oxide of iron; the tints varying with the proportion of the latter.

Clouet says, in his Memoir on Enamels, that a fine yellow is obtained with pure oxide of silver, and that it is merely necessary to spread a thin coat of it on the spot to be coloured. The piece is then exposed to a moderate heat, and withdrawn as soon as this has reached the proper point. The thin film of metallic silver revived on the surface being removed, the place under it will be found tinged of a fine yellow, of hardly any thickness. As the pellicle of silver has to be removed which covers the colour, it is requisite to avoid fixing this film with fluxes: and it ought therefore to be applied after the fusion of the rest. The yellows require in general but little alkaline flux, as they answer better with one of a metallic nature.

Green Enamel.—It is known that a green colour may be produced by a mixture of yellow and blue; but recourse is seldom had to this practice for enamels, as they can be obtained almost always directly with the oxide of copper; or, still better, with the oxide of chrome, which has the advantage of resisting a strong heat.

Chemists describe two oxides of copper, the protoxide of an orange colour, which communicates its colour to enamels, but it is difficult to fix; the deutoxide is blue in the state of hydrate, but blackish-brown when dry, and it colours green all the vitreous combinations into which it enters. This oxide requires, at most one or two proportions of flux, either saline or metallic, to enter into complete fusion; but a much smaller dose is commonly taken, and a little oxide of iron is introduced. To 4 pounds of frit, for instance 2 ounces of oxide of copper and 48 grains of red oxide of iron are used; and the ordinary measures are pursued for making very homogeneous enamel.

The green produced by oxide of chrome is much more solid; it is not affected by a powerful fire, but it is not always of a fine shade. It generally inclines too much to the dead-leaf yellow, which depends on the degree of oxygenation of the chrome.

Red Enamel.—We have just stated, that protoxide of copper afforded a fine colour when it could be fixed, a result difficult to obtain on account of the fugitive nature of this oxide; slight variations of temperature enabling it to absorb more oxygen, The proper point of fusion must be seized for taking it from the fire whenever the desired colour is brought out. Indeed, when a high temperature has produced peroxidisement, this may be corrected by adding some combustible matter, as charcoal, tallow, tartar, &c. The copper then returns to its minimum of oxidisement, and the red colour which had vanished, reappears. It is possible, in this way, and by pushing the heat a little, to accomplish the complete reduction of a part of the oxide; and the particles of metallic copper thereby disseminated in a reddish ground, give this enamel the aspect of the stone called *aventurine*. The surest and easiest method of procuring protoxide of copper is to boil a solution of equal parts of sugar, and sulphate or rather acetate of copper, in four parts of water. The sugar takes possession of a portion of the oxygen of the cupreous oxide, and reduces it to protoxide; when it may be precipitated in the form of a granular powder of a brilliant red. After about two hours moderate ebullition, the liquid is set aside to settle, decanted off the precipitate, which is washed and dried.

The protoxide properly employed by itself, furnishes a red which vies with the finest carmine, and by its means every tint may be obtained from red to orange, by adding a greater or smaller quantity of peroxide of iron.

The preparations of gold, and particularly the oxide and purple of Cassius, are likewise employed with advantage to colour enamel red, and this composition resists a powerful fire tolerably well. For some time back, solutions of gold, silver, and platinum have been used with success instead of their oxides; and in this way, a more intimate mixture may be procured, and, consequently, more homogeneous tints.

Black Enamel.—Black enamels are made with peroxide of manganese or protoxide

of iron; to which more depth of colour is given with a little cobalt. Clay alone, melted with about a third of its weight of protoxide of iron, gives, according to Clouet, a fine black enamel.

Violet Enamel. — The peroxide of manganese in small quantity by itself furnishes, with saline or alkaline fluxes, an enamel of a very fine violet hue; and variations of shade are easily had, by modifying the proportions of the elements of the coloured frit. The great point is to maintain the manganese in a state of peroxidation, and, consequently, to beware of placing the enamel in contact with any substance attractive of oxygen.

Such are the principal coloured enamels hitherto obtained by means of metallic oxides; but since the number of these oxides is increasing every day, it is to be wished the new trials be made with such as have not yet been employed. From such researches some interesting results would unquestionably be derived.

Of painting on Enamel.—Enamelling is only done on gold and copper; for silver swells up, and causes blisters and holes in the coat of enamel. All enamel paintings are, in fact, done on either copper or gold.

If on gold, the goldsmith prepares the plate that is to be painted upon. The gold should be 22 carats fine: if purer, it would not be sufficiently stiff; if coarser, it would be subject to melt; and its alloy should be half white and half red, that is, half silver and half copper; whereby the enamel with which it is covered will be less disposed to turn green, than if the alloy were entirely copper.

The workman must reserve for the edge of the plate a small fillet, which he calls the *border*. This ledge serves to retain the enamel, and hinders it from falling off when applied and pressed on with a spatula. When the plate is not to be counter-enamelled, it should be charged with less enamel, as, when exposed to heat, the enamel draws up the gold to itself, and makes the piece convex. When the enamel is not to cover the whole plate, it becomes necessary to prepare a lodgment for it. With this view, all the outlines of the figure are traced on the plate with a black-lead pencil, after which recourse is had to the graver.

The whole space enclosed by the outlines must be hollowed out in *bas-relief*, of a depth equal to the height of the fillet, had the plate been entirely enamelled. This sinking of the surface must be done with a flat graver as equally as possible; for if there be an eminence, the enamel would be weaker at that point, and the green would appear. Some artists hatch the bottom of the hollow with close lines, which cross each other in all directions; and others make lines or scratches with the edges of a file broken off square. The hatchings or scratches lay hold of the enamel which might otherwise separate from the plate. After this operation, the plate is cleansed by boiling it in an alkaline lye, and it is washed first with a little weak vinegar, and then with clear water.

The plate thus prepared is to be covered with a coat of white enamel, which is done by bruising a piece of enamel in an agate or porcelain mortar to a coarse powder like sand, washing it well with water, and applying it in the hollow part in its moist state. The plate may meanwhile be held in an ordinary forceps. The enamel powder is spread with a spatula. For condensing the enamel powder, the edges of the plate are struck upon with a spatula.

Whenever the piece is dry, it is placed on a slip of sheet iron perforated with several small holes, see *fig.* 720, which is laid on hot cinders; and it is left there until it ceases to steam. It must be kept hot till it goes to the fire; for were it allowed to cool it would become necessary to heat it again very gradually at the mouth of the furnace of fusion, to prevent the enamel from decrepitating and flying off.

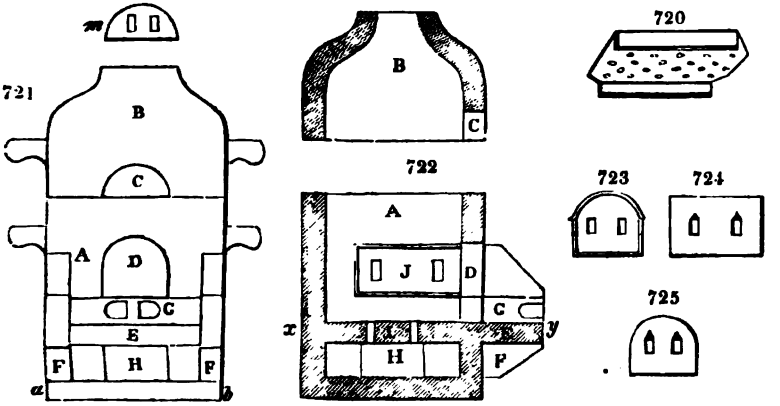
Before describing the manner of exposing the piece to the fire, we must explain the construction of the furnace. It is square, and is shown in front elevation in *fig.* 721. It consists of two pieces, the lower part A, or the body of the furnace, and the upper part B, or the capital, which is laid on the lower part, as is shown in *fig.* 722, where these two parts are separately represented. The furnace is made of good fire-clay, moderately baked, and resembles very closely the assay or cupellation furnace. Its inside dimensions are 9 inches in width, 13 inches in height in the body, and 9 in the capital. Its general thickness is 2 inches.

The capital has an aperture or door, C, *fig.* 721, which is closed by a fire-brick stopper *m*, when the fire is to be made active. By this door fuel is supplied.

The body of the furnace has likewise a door D, which reaches down to the projecting shelf E, called the bib (*mentonnière*), whose prominence is seen at E, *fig.* 721. This shelf is supported and secured by the two brackets, F, F; the whole being earthenware. The height of the door D, is abridged by a peculiar fire brick G, which not only covers the whole projection of the shelf E, but enters within the opening of the door D, filling its breadth, and advancing into the same plane with the inner surface

of the furnace. This plate is called the hearth; its purpose will appear presently; it may be taken out and replaced at pleasure, by laying hold of the handle in its front.

Below the shelf E, a square hole, H, is seen, which serves for admitting air, and for extracting the ashes. Similar holes are left upon each side of the surface, as is shown in the ground plan of the base, *fig.* 722, at H.



On a level with the shelf, in the interior of the furnace, a thin fire-tile I rests, perforated with numerous small holes. This is the grate represented in a ground view in *fig.* 720. *Figs.* 723, 724, 725, represent, under different aspects, the muffle. *Fig.* 722 shows the elevation of its further end; *fig.* 724 its sides; and *fig.* 725 its front part. At J, *fig.* 722, the muffle is seen in its place in the furnace, resting on two bars of iron, or, still better, on ledges of fire-clay, supported on brackets attached to the lateral sides of the furnace. The muffle is made of earthenware, and as thin as possible. The fuel consists of dry beech-wood, or oaken branches, about an inch in diameter, cut to the length of nine inches, in order to be laid in horizontal strata within the furnace, one row only being placed above the muffle. When the muffle has attained to a white red heat, the sheet iron tray, bearing its enamel plate, is to be introduced with a pair of pincers into the front of the muffle, and gradually advanced towards its further end. The mouth of the muffle is to be then closed with two pieces of charcoal only, between which the artist may see the progress of the operation. Whenever the enamel begins to flow, the tray must be turned round on its base to insure equality of temperature; and as soon as the whole surface is melted, the tray must be withdrawn with its plate, but slowly, lest the vitreous matter be cracked by sudden refrigeration.

The enamel plate, when cold, is to be washed in very dilute nitric acid, and afterwards in cold water, and a second coat of granular enamel paste is to be applied, with the requisite precautions. This being passed through the fire, is to be treated in the same way a third time, when the process will be found complete. Should any chinks happen to the enamel coat, they must be widened with a graver, and the space being filled with ground enamel, is to be repaired in the muffle. The plate, covered with a pure white enamel, requires always to be polished and smoothed with sandstone and water, particularly if the article have a plane surface; and it is then finally glazed at the fire.

The painting operation now follows. The artist prepares his enamel colours by pounding them in an agate mortar, with a pestle of agate, and grinding them on an agate slab, with oil of lavender, rendered viscid by exposure to the sun in a shallow vessel, loosely covered with gauze or glass. The grinding of two drachms of enamel pigment into an impalpable powder will occupy a labourer a whole day. The painter should have alongside of him a stove in which a moderate fire is kept up, for drying his work whenever the figures are finished. It is then passed through the muffle.

The following was the process adopted by Henry Bone, R. A., and his son, the late Henry Pierce Bone, who have produced the largest enamels ever painted; and beyond the time and consequent expense there appears no practical limit to the size of enamel paintings.

Preparing the plate.—For small plates (up to two inches long) *pure* gold is the best material. Silver (quite pure) is also used, but is apt to get a disagreeable yellow colour at the edges by repeated firings. For larger sizes, copper is used. The copper

should be annealed until quite free from spring, and then cleaned with dilute sulphuric acid (one part acid, four water , and shaped in a wooden mould, afterwards used in making the plate so as to produce a convex surface varying according to the size of the plate, taking care that the shaping does not reproduce the spring in the copper, in which case the process must be repeated. If the plate is not raised in the centre, in the course of repeated firings the corners will rise irregularly, producing undulations over the plate, perfect flatness being next to impossible for large pictures. The copper is then laid face downwards on the convex wooden mould used for shaping, and enamel ground fine with water is spread over it with a small bone spoon ; when covered, a fine cloth doubled is pressed gently on it to absorb the water, and then it is smoothed with a steel spatula. This forms the back of the plate, and when fired this part is finished. The copper is now reversed on a convex board the exact counterpart of the other, and covered with white enamel ground fine in the same way as above. The plate is now ready for firing, and after it has been fired and cooled the surface must be ground smooth with a flat piece of flint or other hard substance, with silver sand and water. It must next be covered with a softer and more transparent kind of enamel called flux, ground and spread on in the same way as the first enamel, but this time only on the face of the plate. This is fired as before, and when cool the surface must be again ground smooth, and when glazed in the furnace the plate is finished. For the first coat a white solid enamel is used to prevent the green colour from the oxidised copper showing through; the second coat is a softer enamel, to enable the colours used to melt with less heat.

Firing. — The plate is placed on a planche of firestone, or well baked Stourbridge clay, supported on a bed of whiting, thoroughly dried in the furnace, the exact shape of the plate as originally made, which must be used in all subsequent firings. After the whiting is formed in the shape of the plate it should be notched with a flat knife diagonally across, as in the accompanying diagram. The use of this is to produce an effect of diagonal bracing while the plate cools, and experience has shown that it tends considerably to keep the plate in its original shape. When the plate is small (up to three inches in length) it may be annealed for passing into the hot muffle as follows: — The planche bearing the plate may be placed on another planche heated in the muffle and placed in the front of the muffle for a few minutes, until the steam of the plate or the oil of the picture shall have evaporated; it may then be put in the mouth of the muffle and gradually inserted to the hottest part. After firing it should be placed on another hot planche and allowed to cool gradually. Large pictures require a different arrangement of the furnace. Over the muffle there should be a fixed iron annealing box, with an iron shelf and door. The bottom should be of cast iron about one inch thick. This should be so arranged that when the muffle attains a white heat the bottom of the annealing box should be of a brightish red at the back, and a dull blood red in front. Large pictures should be placed on the bottom of the box before the furnace is lit, and the larger the size of the picture the slower should the furnace be brought to its full heat, so as to allow five or six hours for the largest size, and two or three for smaller plates. When fired the picture should be returned to the shelf of the annealing box, and left there till quite cold, for which purpose large plates require at least twelve hours. The colours used are mostly the same as those prepared for jewellers and glass painters.

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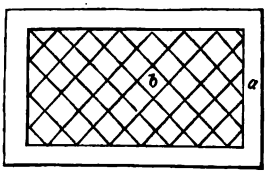

a Planche.
b Bed of whiting.

Enamelling at the Lamp. — The art of the lamp enameller is one of the most agreeable and amusing that we know. There is hardly a subject in enamel which may not be executed by the lamp-flame in very little time, and more or less perfectly, according to the dexterity of the artist, and his acquaintance with the principles of modelling.

In working at the lamp, tubes and rods of glass and enamel must be provided, of all sizes and colours.

The enamelling table is represented in *fig.* 727, round which several workmen, with their lamps, may be placed, while the large double bellows D below is set a-blowing by a treadle moved with the foot. The flame of the lamp, when thus impelled by a powerful jet of air, acquires surprising intensity. The bent nozzles or tubes A, A, A, A, are made of glass, and are drawn to points modified to the purpose of the enameller.

Fig. 728 shows, in perspective, the lamp A of the enameller standing in its cistern B; the blowpipe C is seen projecting its flame obliquely upwards. The blowpipe is adjustable in an elastic cork D, which fills up exactly the hole of the table into which it enters. When only one person is to work at a table provided with several

lamps, he sits down at the same side with the pedal of the bellows; he takes out the other blowpipes, and plugs the holes in the table with solid corks.

The lamp is made of copper or tin plate, the wick of cotton threads, and either tallow or oil may be used. Between the lamp and the workman a small board or

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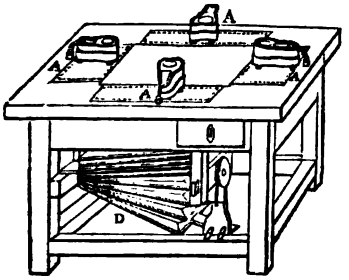

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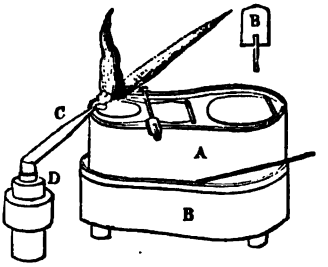

sheet of white iron B, called the screen, is interposed to protect his eyes from the glare of light. The screen is fastened to the table by a wooden stem, and it throws its shadow on his face.

The enamelling workshop ought to admit little or no daylight, otherwise the artist, not perceiving his flame distinctly, would be apt tocommit mistakes.

It is impossible to describe all the manipulations of this ingenious art, over which taste and dexterity so entirely preside. But we may give an example. Suppose the enameller wishes to make a swan. He takes a tube of white enamel, seals one of its ends hermetically at his lamp, and while the matter is sufficiently hot, he blows on it a minikin flask, resembling the body of the bird; he draws out, and gracefully bends the neck; he shapes the head, the beak, and the tail; then, with slender enamel rods of a proper colour, he makes the eyes; he next opens up the beak with pointed scissors; he forms the wings and the legs; finally attaching the toes, the bird stands complete.

The enameller also makes artificial eyes for human beings, imitating so perfectly the colours of the sound eye of any individual as to render it difficult to discover that he has a blind and a seeing one.

It is difficult to make large articles at the blowpipe; those which surpass 5 or 6 inches become nearly unmanageable by the most expert workmen.

Enamelling of Cast Iron and other Hollow Ware for Saucepans, &c. In December, 1799, a patent was obtained for this process by Dr. Samuel Sandy Hickling. His specification is subdivided into two parts: —

1. The coating or lining of iron vessels, &c., by fusion with a vitrifiable mixture, composed of 6 parts of calcined flints, 2 parts of *composition* or Cornish stone, 9 parts of litharge, 6 parts of borax, 1 part of argillaceous earth, 1 part of nitre, 6 parts of calx of tin, and 1 part of purified potash. Or, 2ndly,

8 parts of calcined flints, 8 red lead, 6 borax, 5 calx of tin, and 1 of nitre. Or, 3rdly,

12 of potter's composition, 8 borax, 10 white lead, 2 nitre, 1 white marble calcined, 1 argillaceous earth, 2 purified potash, and 5 of calx of tin. Or, 4thly,

4 parts calcined flint, 1 potter's composition, 2 nitre, 8 borax, 1 white marble calcined, ½ argillaceous earth, and 2 calx of tin.

Whichever of the above compositions is taken, must be finely powdered, mixed, fused, the vitreous mass is to be ground when cold, sifted, and levigated with water. It is then made into a pap with water or gum water. This pap is smeared or brushed over the interior of the vessel, dried and fused with a proper heat in a muffle.

Calcined bones are also proposed as an ingredient of the flux.

The fusibility of the vitreous compounds is to vary according to the heat to be applied to the vessel, by using various proportions of the silicious and fluxing materials. Colours may be given, and also gilding.

The second part or process in his specification describes certain alloys of iron and nickel, which he casts into vessels, and lines or coats them with copper precipitated from its saline solutions. It also describes a mode of giving the precipitated copper an enamel surface by acting upon it with bone ashes and zinc with the aid of heat.

A factory of such enamelled hollow wares was carried on for some time, but it was given up for want of due encouragement.

A patent was granted to Thomas and Charles Clarke on the 25th of May, 1839, for a method of enamelling or coating the internal surfaces of iron pots and saucepans, in

such a way as shall prevent the enamel from cracking or splitting off from the effects of fire. This specification prescribes the vessel to be first cleaned by exposing it to the action of dilute sulphuric acid (sensibly sour to the taste) for three or four hours, then boiling the vessel in pure water for a short time, and next applying the composition. This consists of 100 lbs. of calcined ground flints; 50 lbs. of borax, calcined, and finely ground with the above. That mixture is to be fused and gradually cooled.

40 lbs. weight of the above product is to be taken with 5 lbs. weight of potter's clay; to be ground together in water until the mixture forms a pasty consistent mass, which will leave or form a coat on the inner surface of the vessel about one-sixth of an inch thick. When this coat is set, by placing the vessel in a warm room, the second composition is to be applied. This consists of 125 lbs. of white glass (without lead), 25 lbs. of borax, 20 lbs. of soda (crystals), all pulverised together and vitrified by fusion, then ground, cooled in water, and dried. To 45 lbs. of that mixture, 1 lb. of soda is to be added, the whole mixed together in hot water, and when dry pounded; then sifted finely and evenly over the internal surface of the vessel previously covered with the first coating or composition whilst this is still moist. This is the glazing. The vessel thus prepared is to be put into a stove, and dried at the temperature of 212° Fahr. It is then heated in a kiln or muffle like that used for glazing china. The kiln being brought to its full heat, the vessel is placed first at its mouth to heat it gradually, and then put into the interior for fusion of the glaze. In practice it has been found advantageous also to dust the glaze powder over the fused glaze, and apply a second fluxing heat in the oven. The enamel, by this double application, becomes much smoother and sounder.

Messrs. Kenrick, of West Bromwich, having produced in their factory and sent into the market some excellent specimens of enamelled saucepans of cast iron, were sued by Messrs. Clarke for the invasion of their patent rights; but after a long litigation in Chancery the patentees were nonsuited in the Court of Exchequer. The previous process of cleansing with dilute sulphuric acid appeared by the evidence on the trial to have been given up by the patentees, and it was also shown by their own principal scientific witness that a good enamelled iron saucepan could be made by Hickling's specification. In fact, the formulæ by which a good enamel may be compounded are almost innumerable; so that a patent for such a purpose seems to be untenable, or at least most easily evaded. Dr. Ure exposed the finely enamelled saucepans of Messrs. Kenrick to very severe trials, having fused even chloride of calcium in them, and found them to stand the fire very perfectly without chipping or cracking. Such a manufacture is one of the greatest improvements recently introduced into domestic economy; such vessels being remarkably clean, salubrious, and adapted to the most delicate culinary operations of boiling, stewing, making of jellies, preserves, &c. They are also admirably fitted for preparing pharmaceutical decoctions, and ordinary extracts.

The enamel of these saucepans is quite free from lead, in consequence of the glass which enters into its composition being quite free from that metal. In several of the saucepans which were at first sent into the market, the enamel was found on analysis to contain a notable proportion of oxide of lead. In consequence of the quantity of borax and soda in the glaze, this oxide was so readily acted upon by acids that sugar of lead was formed by digesting vinegar in them with a gentle heat.

Enamelled iron saucepans had been many years ago imported from Germany, and sold in London. Dr. Ure had occasion to analyse their enamel, and found that it contained abundance of litharge or oxide of lead. The Prussian government has issued an edict prohibiting the use of lead in the enamelling of saucepans, which are so extensively manufactured in Peiz, Gleiwitz, &c. Probably the German ware sent to England was fabricated for exportation, with an enamel made to flux easily by a dose of litharge.

A suitable oven or muffle for lining or coating metals with enamel may have the following dimensions: —

The outside, 8 feet square, with 14-inch walls; the interior muffle, 4 feet square at bottom, rising 6 inches at the sides, and then arched over; the crown may be 18 inches high from the floor; the muffle should be built of fire-brick, 2½ inches thick. Another arch is turned over the first one, which second arch is 7 inches wider at the bottom, and 4 inches higher at the top. A 9-inch wall under the bottom of the muffle at its centre divides the fire-place into two, of 16 inches width each, and 3 feet 3 inches long. The flame of the fire plays between the two arches and up through a 3-inch flue in front, and issues from the top of the arch through three holes, about 4 inches square. These open into a flue, 10 × 9 inches, which runs into the chimney.

The materials for the enamel body (ground flint, potter's clay, and borax) are first mixed together, and then put into a reverberatory furnace, 6 feet 7 inches long, by

3 feet 4 inches wide, and 12 inches high. The flame from an 18-inch fire-place passes over the hearth. The materials are spread over the floor of the oven, about 6 inches thick, and ignited or fritted for 4 or 5 hours, until they begin to heave and work like yeast, when another coating is put on the top, also 6 inches thick, and fired again, and so on the whole day. If it be fired too much it becomes hard and too refractory to work in the muffles. The glaze is worked in an oven similar to the above. It may be composed of about one-half borax and one-half of Cornish stone (partially decomposed granite) in a yellowish powder procured from the potteries. This is fritted for 10 hours, and then fused into a glass which is ground up for the glaze.

ENAMELLED LEATHER. Leather glazed upon one surface, the so-called enamelling composition being in all respects analogous to the ordinary varnishes. Instead of enamelling the grain surface, as is usually done, Mr. Nossiter removes that surface by splitting or buffing, and then produces what is called "a finish" upon the surface thus formed, by means of a roller, or glass instrument. The flesh side of the skin may be thus prepared for enamelling; and it is less liable to crack, and the enamel to become cloudy on it than the grain side. See LEATHER.

ENCAUSTIC PAINTING. A mode of painting with heated or burnt wax, which was practised by the ancients. The wax, when melted, was mixed with as much colour, finely powdered, as it could imbibe, and then the mass was spread on the wall with a hot spatula. When it became cold the designer cut the lines with a cold pointed tool, and other colours were applied and melted into the former. Many modifications of the process have been employed. Amongst the moderns, the term has been improperly given to some cements, which have nothing of an encaustic character about them.

ENCAUSTIC TILES. See TILES and TESSERÆ.

ENDOGENOUS. See EXOGENOUS.

ENGRAVING, a word derived from *ev*, *in*, and *γράφω*, to *grave* or *write*, is the art of executing designs or devices, upon metal, stones, and other hard substances. In the common acceptation of the word in the present day, it means the execution of such works on plates of copper or steel, for the purpose of obtaining from them impressions in ink or some other coloured fluid. Engraving, in the widest sense of the term, is the oldest of the fine arts; at least, the Scriptures mention it before any reference is made either to painting or sculpture. In the Book of Exodus, ch. xxviii. v. 29, we read that "Aaron shall bear the names of the children of Israel in the breast-plate of judgment upon his heart;" and again, in the same chapter, Moses is commanded to "make a plate of pure gold, and grave upon it, like the engravings of a signet, Holiness to the Lord." Further on, in the 35th chapter of the same book, Moses speaks of Bezaleel, the son of Uri, as a man "filled with the spirit of God, in wisdom, in understanding, and in knowledge, and in all manner of workmanship; and to devise curious works, to work in gold, and in silver, and in brass, and in the cutting of stones," &c. Of him and of Aholiab it is said,—"Them hath he filled with wisdom of heart, to work all manner of work of the engraver," &c. &c. These extracts will suffice to show the antiquity of the art of incising, or cutting hard substances; whether or not it had its origin at a period anterior to the time of Moses there is no record, but it is not improbable that the Israelites acquired some knowledge of the art from the Egyptians during their lengthened captivity, an assumption strengthened by the fact that numerous specimens of hieroglyphic engraving, on metal plates and on stone, have been discovered in Egypt and brought to this country: their dates, however, have not, in all cases, been ascertained with certainty.

It is unnecessary to trace back all that might be written respecting the state of this art among the nations of antiquity in its various applications; but as an example of its adoption for a purpose altogether practical, a passage from Herodotus may be adduced. This historian, referring to a period about 500 years before the Christian era, says:—"Aristagoras exhibited to the king of Sparta a tablet, or plate, of brass, on which was inscribed every part of the habitable world, the seas, and the rivers;" or, in other words, Aristagoras, who was a native of Cuma, had in his possession a metallic map. Moreover, as it is intended to limit this notice to the art of engraving on steel or copper for printing purposes, we pass over those branches or departments of the art that relate to die-sinking, seal-engraving, and engraving on coins, the latter a common process with the ancient Britons and Saxons, who also, according to the opinion of many modern antiquarians, used to ornament their weapons of war with designs cut by the graving-tool.

The transition from all previous methods of engraving, to that which in some degree assimilates to what is now practised as the result of the discovery of printing, has been thus described by the late Mr. Landseer, who quotes an earlier writer, Mr. Strutt:—"Soon after the conquest (though, from other information, I think it must have been at the least 250 years from that memorable era) a new species of engraving, entirely

different from the mingled work of the engraver, goldsmith, and chaser, which had preceded it, was introduced into, or invented in, England, of which there is scarcely an old country church of any consequence, but affords some curious specimens, and England more than any other nation in Europe. The brass plates on our old sepulchral monuments are executed entirely with the graver, the shadows being expressed by lines or strokes, strengthened in proportion to the required depth of shade, and occasionally crossed with other lines a second and, in some instances, a third time, precisely in the same manner as a copper plate is engraven that is intended for producing impressions. These engraved effigies are commonly found on those horizontal tombstones which form part of the pavement within the churches; and the feet of the congregation, which kept the lights bright by friction, filled the incisions with dust, and thus darkened the shades: very neat or exquisite workmanship is not therefore expected; yet some of them bear no small evidence of the abilities of the monks, or other workmen, by whom they were performed." Impressions, technically called "rubbings," are taken from these monumental brasses by antiquarians, for the purpose of illustrating works in archæology. The process is simple enough; a sheet, or sheets, as may be required, of white paper, sufficiently large to cover the brass tablet, are laid upon it; these are then rubbed over with a lump of "shoemaker's heel-ball," a composition of wax and lamp-black, which leaves on the paper an impression of the raised portions of the metal.

The fifteenth century, which must always be considered as the dawn of universal light and knowledge, gave to the world the art of printing, and from this invention arose a new era in the art of engraving: the earliest method of printing, both books and illustrations, was, as is described under the article *Wood Engraving*, from engraved blocks or tablets. It seems singular that, though engraving on various metals had been practised long before that on wood, no attempt had ever been made to obtain impressions from the plates; like many other important discoveries, this is said to be the result of accident. Vasari, the historian of Italian art, says that, in the year 1460, Maso, or Thomaso Finiguerra, a Florentine goldsmith, chanced to let fall a small engraved plate, on which, as was customary with engravers, he had rubbed a little charcoal and oil, that he might the better see the state of his work, into some melted sulphur, and observing that the exact impression of his engraving was left on the sulphur, he repeated the experiment, by passing a roller gently over it. It was successful, and Finiguerra imparted his discovery to Baldini, also a goldsmith of Florence, by whom it was communicated to others. But the most probable origin of the art of printing from metallic plates, is that which is attributed to the early Italian workers in *niello*, or inlaid modeling work, an art used for ornamenting table utensils, swords, armour, &c.: this art consisted in cutting or engraving the required design on silver, and filling up the incisions with a black composition, said to be made of silver and lead, which, from its dark colour, was called by the ancients *nigellum*, abbreviated by the Italians into *niello;* this mixture, when run into the engraved lines, produced a regular effect of *chiar-oscuro* in the entire work. From these engraved plates or objects, the artists in *niello*, who were the goldsmiths and silversmiths of that period, were accustomed to take impressions, by smoking the metal, and then, after cleaning the smooth surface with oil, impressing upon it a piece of damp paper. From such an origin, or from some other very similar to it, undoubtedly, came the art of chalcography, or plate-printing, and it is equally certain, that the art of engraving with the *burin*, or as it is now called, "line engraving," arose in the workshops of the gold and silversmiths.

The practice of making paper from rags, without which the former art would have proved comparatively useless, had been adopted generally throughout Europe towards the end of the fourteenth century, whereby the chief obstacle to printing was removed.

Not very long after the discovery of plate-printing, the engravers, separating themselves from the manufacturing goldsmiths and chasers, formed themselves into a distinct body, opened schools for pupils, and took up their rightful position among the artists of the time.

Italy and Germany have each contended for the honour of being the first discoverers of the art of printing from engraved plates, but the best authorities give to the former country the priority of claim, though the Germans, to whom the printing press was earliest known, soon surpassed their rivals, both in that art and in engraving: but they have not always maintained the superiority.

The principal Italian engravers, contemporary with, or immediately following Finiguerra, were Baldini, Botticelli, and Andrew Mantegna; in Germany, the names of Martin Schön, who began his career about the year 1460, and engraved his own compositions, Israel Van Mecheln, Leydenwurf, and Wolgemup, stand prominently forward; but it was not till the commencement of the sixteenth century, that engraving occupied a high position among the arts of either country. Singularly enough, Italy, *Germany*.

and Holland, produced each an engraver, whose works to this day are held in the highest estimation; while Marc Antonio Raimondi (born at Bologna, in 1488), and Albert Durer (born at Nuremberg, in 1471), were respectively practising the art in Italy and Germany, Lucas Van Leyden (born at Leyden, in 1494) disputed in the Low Countries the palm with these distinguished competitors. As these artists have ever been considered the patriarchs of engraving, a few words respecting the merits of each may not inappropriately be introduced here.

Travelling to Venice for improvement, Marc Antonio saw there some prints, by Albert Durer, of the life of the Virgin; these he copied with tolerable fidelity; he soon, however, quitted Venice, and went to Rome, where he made the acquaintance of Raffaelle, a large number of whose works he engraved. "The purity of his outlines," says Bryan, "the beautiful character and expression of his heads, and the correct drawing of the extremities, establish his merits as a perfect master of design." His works frequently exhibit a deficiency in reflex light and harmony of *chiar-oscuro*, and he appears to have been ignorant of the principles of rendering local colour, or tints, in the abstract; neither did he attempt, or else was unable, to express the various textures of substances: these are, however, minor defects by comparison, and may easily be excused when the state of art generally at that period is taken into account. "Raffaelle," says Landseer, "was Marc Antonio's object; and the blandishments, the splendour, and the variety which would have been indispensably necessary to the translation of Correggio or Titian, were not called for here."

Albert Durer, the head of the German school of engraving, laboured under disadvantages with which the artists of Italy had not to contend: the latter had frequently, if not constantly, the graceful forms and flowing outlines of antique sculpture made familiar to them: and hence their works exhibit, even from the earliest time, much greater elegance of manner, and refinement in execution, than those of Germany. The engravings by Durer, whom Landseer supposes to be the first who corroded his plates with *aqua-fortis*, partake largely of the stiff, dry, and gothic manner, peculiar to the country and the period, and which to this day is more or less discernible in German art. If Durer had been so fortunate as to have had the pictures of Raffaelle to engrave, he would doubtless have left the world prints of a very different character than those we now see: we should have had more grace of expression, and freedom of lines, but less originality in the style of execution, and, probably, less vigour. Durer engraved only his own designs, and his faults or defects were those of his time: but, notwithstanding his Gothic bondage, nothing that has ever appeared in more recent periods, surpasses, in executive excellence, his "St. Jerome seated in a Room;" here all the objects are rendered with a fidelity, that only the camera could emulate. That very remarkable and mysterious composition known as "The Death's Head," is also a masterly example of execution: the helmet, with all its pomp of heraldic appendage, and the actual and reflex lights on its polished surface, are characteristically, though minutely, expressed: the skull is accurately drawn, and its bony substance unmistakably described. The head of the Satyr, with its beard and wild redundance of snaky tangled hair, has considerable and well-managed breadth of light and shade: the drapery of the female, quaint as it is in style, is not, as we see it in Durer's other works, hard, stiff, and formal, but relaxes into freedom and simplicity, and has quite a silky texture; in fact, it approaches very nearly to what we now call "picturesque composition of forms, and light and shade." Durer's etching appears to have been bitten in, or corroded with the acid, at once. He seems either not to have known, or did not care to practise, the process now adopted, of "stopping out," for the purpose of producing gradation of shade. The admirable wood engravings by this artist are referred to in their proper place.

The works of Van Leyden, the Dutchman, are even more gothic in taste and style than those of Durer, with whom he is said to have been intimately acquainted: they exhibit the same amount or degree of stiff, angular drapery; as much, perhaps even more, inattention to grace and dignity of form, without his fertile imagination, his occasional vigour, and his truthful observation of individual nature. His execution is neat and clearly defined, but his plates are deficient in firmness and harmonious effect, and his lines are without variation in substance; those that represent near objects, and those that express objects at a distance, are equally fine and delicate; hence the monotony apparent in his prints. They are almost entirely sacred or legendary subjects, from his own designs; among the finest are "The Temptation of St. Anthony," engraved in 1509, when he was only thirteen years of age; "The Crucifixion," and the "Adoration of the Magi."

It would be beyond the province of this notice to record the progress of the art through the continental schools till it took root in England; yet a short history of its introduction and growth on our soil, may not be considered out of place.

Until the middle of the last century, neither painting nor engraving had attained

any eminence in this country; the latter art, especially, was practised chiefly by foreigners, as Hollar, Simon, Vaillant, Blooteling, &c.; previously to whom we had, of our own countrymen, Faithorne, an admirable engraver of portraits, Payne, White, and one or two others of inferior merit; but, with the exception of Faithorne, none whose works are now held in much esteem. The encouragement afforded by George III., almost as soon as he ascended the throne, to the fine arts generally, and the establishment of the Royal Academy, which offered to artists a position in the country they had never before held, gave an impulse to every section, or branch, of art professors. Hogarth's name had, however, become widely known many years before: his numerous plates, all of them from his own designs, are to this day much sought after, not so much, perhaps, for any especial excellence as examples of fine engravings, as for the talent and genius which the subjects display. "Hogarth composed comedies as much as Moliere," was the remark of Walpole: he died just as art was beginning to be recognised and patronised in England. Francis Vivares, a Frenchman by birth, but long settled in England, where he studied the art under Chatelain, carried landscape-engraving to a high point of excellence; some of his prints after pictures by Claude and Gaspar Poussin, exhibit remarkable freedom in the foliage of the trees, and truth in the texture of the various objects introduced in the landscape. Woollett, born at Maidstone, in Kent, who died in 1785; and Sir Robert Strange, a native of one of the Orkney islands, who died in 1792, advanced the art still further; indeed, it is a question whether engraving has ever found more able exponents than these two distinguished men: the latter engraved several portraits, which have rarely been surpassed at any period in the history of art. The works of both these engravers are characterised by bold and vigorous execution, produced by the combined use of the etching-needle and the graver. Cotemporary with these, or their immediate successors, were Browne, who sometimes worked with Woollett, Bartolozzi, Hall, Rooker, Green, Ryland, Watts, Sharp, McArdell, Smith, Earlom, &c.; all aided, by their proficiency, to uphold the honour of the art; while John Landseer, father of the living painters, Raimbach, Engleheart, Pye, and John Burnet, — the last two yet with us, — may be regarded as the chief connecting links between the past generation and the present.

Engraving on metal plates may be classed under the following heads: — *Etching*, *line*, *mezzotinto*, *chalk*, *stipple*, and *aquatint*. Before describing the processes of working these respective kinds, a notice of the instruments used by the engraver is necessary. These, with some modifications, are employed in all the styles.

The *etching-point*, or *needle*, is a stout piece of steel-wire inserted into a handle; two or three, varying in thickness, are requisite, and they should be frequently and carefully sharpened. This is best done by turning the needle round in the fingers while rubbing it on a hone, and afterwards on a leather strop prepared with putty powder, or on an ordinary razor-strop, to take off any roughness, and to make it perfectly round.

The *dry-point* is a similar instrument, used for delicate lines: it must be sharpened on the hone till a fine conical point is obtained.

The *graver*, or *burin*, is the principal instrument employed in engraving: several are required, differing from each other in form, from the extreme *lozenge* shape to the *square*; the former being used for cutting fine lines, the latter for broad: the graver fits into a handle about five inches and a half long, and it should be well-tempered before using, an operation requiring great care. The angle at the meeting of the two lower sides is called the *belly*, and the breadth of the end, the *face*. To sharpen the former, lay one of the flat sides of the graver on the oilstone, keeping the right arm tolerably close to the side, and rub it firmly; next rub the other in the same way: the face is sharpened by holding it firmly in the hand, with the belly upwards, in a slanting direction; rub the end rather gently on the stone, at an angle of about forty-five degrees, taking care to carry it evenly along until it acquires a very sharp point: this being done, hold the engraver a little more upright to square the point, which a very few rubbings will effect. The graver for *line* work must be slightly turned up, to enable the engraver to run it along the plate; otherwise the first indentation he makes on the metal would cause his instrument to become fixed: the graver for *stipple* should be slightly turned down, to make dots only.

The *scraper*, which should have three fluted sides, is used for taking off the *burr* left by the action of the needles on the metal.

The *burnisher* is employed to soften lines that have been *bitten in*, or engraved too dark, and to polish the plate, or get rid of any scratches it may accidentally have received.

The *dabber* used to lay the *etching-ground* evenly, is made by enclosing a small quantity of fine cotton wool very tightly in a piece of silk, the threads of which should be, as much as possible, of uniform thickness.

There are a few other materials which an engraver should have at hand, but they are not of sufficient importance to be mentioned here; we may, however, point out what is technically called a *bridge*, which is nothing more than a thin board for the hand to rest on; it should be smoothly planed, and of a length and breadth in proportion to the size of the plate; at each end a small piece of wood should be fastened to raise it above the plate when covered with wax. A *blind*, made of tissue-paper stretched upon a frame, ought to be placed between the plate and the light, to enable the engraver to see his work on the metal with greater facility and clearness.

In describing the processes of engraving the various styles enumerated above, little more than a general outline of each method can be given, yet sufficient, it may be presumed, to show the nature of the operation: to narrate all the details that might be included in the subject would supply matter enough for a small volume.

Etching may be classed under two heads; that which is made the initiatory process in line-engraving, and that which is known as *painter's-etching*: the latter was practised to some extent by very many of the old painters, particularly those of the Dutch school; and it has also recently come into fashion with many of the artists of our own day, but more for amusement, however, than for any other purpose; in both cases the method of proceeding is alike. Etching is the result of a chemical process resulting in corrosion of the metal on which the design has been laid down, or transferred, in the following manner. The plate must first be covered with a substance already spoken of as *etching-ground*, which may be purchased of most of the principal artists' colourmen, but many engravers make their own: the annexed receipt has been handed to us by Mr. C. W. Sharpe, who has engraved some of the largest steel-plates published recently, as that which he always uses: —

	Parts
Black pitch	1
White wax	1
Burgundy pitch	½
Asphaltum	1
Gum mastic	1

Melt the first three ingredients over a slow fire in a pipkin, then add the other two finely powdered, stirring the whole together all the time; when well mixed, pour it into warm water, and make it up, while warm, into balls; if too soft, a little less wax should be used. Care must be taken not to let the mixture burn during the process of making.

The etching-ground resists the action of the *aqua-fortis*. It should be tied up in a piece of strong silk, and applied thus, which is called *laying the ground*: — Take the plate firmly in a small hand vice; hold it, with the polished face upwards, over a charcoal fire that it may not get smoked, till it is well, but not too much, heated: rub the etching-ground, in the silk, over the plate till it is evenly covered; the wax, melting with the heat, oozes through the silk. To effect a more equal distribution of the *ground*, take the *dabber* and dab the plate gently all over, till it appears of an uniform colour; continue the dabbing till the plate begins to cool, but not longer. The ground is then blackened by being held over the smoke of a candle, or two or three tied together, — wax is far preferable to tallow; keep the plate in motion, so that every part be made equally dark, and also to avoid injury, by burning, to the composition; when cold the plate is ready to receive the design. To transfer this, a very correct outline of the subject is made with a black-lead pencil on a piece of thin hard paper: fasten the tracing, or drawing, at the top edge, with its face downwards, on to the etching-ground, with a piece of banking-wax, described hereafter, and by passing it through a printing-press — such as is used by plate printers, to whom it should be taken — the drawing is transferred to the ground. The *bridge* being laid over the plate, the process of etching may now be commenced; the points, or needles, which are used to complete the design, remove the ground from the metal wherever they pass, and expose the latter to the action of the acid during the process of what is termed *biting in*. The needles with the most tapering points should be used for the skies and distances, changing them for others for the foreground, which generally requires broader and deeper lines. Any error that has been made may be remedied by covering the part evenly with the etching-ground mollified by spirits of turpentine, using a camel's-hair pencil for the purpose; and, when dry, the lines may be re-etched through it.

The next operation is that of *biting in*, performed thus: — A wall or border of *banking-wax* is put round the edge of the plate: this wax, called sometimes *bordering wax*, is made by melting over a slow fire, in a glazed pot, two parts of Burgundy pitch, and one of bees-wax, to which is added when melted, a gill of sweet oil; when cold it is quite hard, but by immersion in warm water it becomes soft and ductile, and must be

applied in this state; it will adhere to the metal by being firmly pressed down with the hand: the object in thus banking up the plate is to prevent the escape of the acid which is to be applied; but a spout or gutter must be left at one corner to pour off the liquid when necessary. Mr. Fielding,—to whose work on the art of engraving we are indebted for some of the practical hints here adduced, availing ourselves, however, of the improvements introduced into modern practice,—recommends the following mixture as the best:—"Procure some strong nitrous acid, and then mix, in a wide mouthed bottle one part of the acid, with five parts of water, adding to it a small quantity of sal ammoniac, in the proportion of the size of a hazel-nut to one pint of acid, when mixed for biting. The advantage of using the sal ammoniac is, that it has the peculiar property of causing the aqua fortis to bite more directly downwards, and less laterally, by which means lines laid very closely together are less liable to run into each other, nor does the *ground* so readily break up." When the mixture is cool — for the acid becomes warm when first mixed with water — pour it on the plate, and let it continue there till the more delicate lines are presumed to be corroded to a sufficient depth; this will probably be in about a quarter of an hour; sweep off the bubbles as they appear on the plate with a camel's-hair pencil, or a feather; then pour off the acid through the gutter at the corner, wash the plate with warm water, and leave it to dry. Next, cover those parts which are sufficiently bitten in with Brunswick black, applying it with a camel's-hair pencil, and leave it to dry; again put on the acid, and let it remain twenty minutes or half an hour, to give the next degree of depth required; and repeat this process of *stopping out* and *biting in*, until the requisite depths are all attained: three *bitings* are generally enough for a *painter's etching*. The work is now complete, unless the graver is to be used upon it, and the banking-wax may be removed, by slightly warming the margin of the plate; and, finally, wash the latter with a soft rag dipped in spirits of turpentine, and rubbing it with olive oil. If, when the plate is cleaned, the engraver finds that the acid has acted as he wishes, he has secured what is technically termed "a good bite."

Steel plates require another method of *biting-in*, on account of their extreme hardness, and liability to rust; the mode just described is applicable only to copper, the metal generally used by painters for their etchings. For steel plates mix together

	Parts
Pyroligneous acid	1
Nitric acid	1
Water	3

This mixture should not be allowed to remain on above a minute; let it be washed off at once, and never use the same water twice; the plate must be set up on its edge, and dried as quickly as possible to avoid rust: the acid may be strengthened where a stronger tint is required.

Rebiting, a process frequently adopted to increase the depth of tint where it is required, or to repair any portion of a plate that has been worn by printing or accidentally injured, is thus performed. The plate must be thoroughly cleaned, all traces of grease removed, by washing it with spirits of turpentine and potass, and polished with whitening; it is then, when warmed over a charcoal fire or with lighted paper, ready for receiving the *ground*; this is laid by using a dabber charged with etching-ground, and carefully dabbing the surface; by this means the surface of the plate only is covered, and the lines already engraved are left clear; any part of the plate that it may not be necessary to *rebite*, must be stopped out with Brunswick black, and then the acid may be poured over the whole, as in the first process.

Etching on soft ground is a style of engraving formerly much practised in imitation of chalk or pencil drawings; since the introduction of lithography, however, it has been entirely abandoned. The *soft ground* is made by adding one part of hog's lard to three parts of common, or hard, etching-ground, unless the weather be very warm, when a smaller quantity of lard will suffice; it should be laid on and smoked in the manner already described. Mr. Fielding gives the following method for working on it. "Draw the outline of your subject faintly on a piece of smooth thin writing paper, which must be at least an inch larger every way than the plate; then damp it, and spread it cautiously on the ground, and turning the edges over, paste down to the back of the plate; in a few hours the paper will be dry, and stretched quite smooth. Resting your hand on the bridge, take an H or HB pencil, and draw your subject on the paper exactly as you wish it to be, pressing strongly for the darker touches, and more lightly for the delicate parts, and, accordingly as you find the ground more or less soft, which depends on the heat of the weather or the room you work in, use a softer or harder pencil, remembering always that the softer the ground the softer the

pencil" (should be). "When the drawing is finished, lift up the paper carefully from the plate, and wherever you have touched with the pencil, the ground will stick to the paper, leaving the copper more or less exposed. A *wall* is then put round the margin, the plate bit in, and if too feeble, rebit in the same way as a common etching, using *hard etching-ground* for the rebite."

Line engraving unquestionably occupies the highest place in the category of the art; and, taking it as a whole, it is the most suitable for representing the various objects that constitute a picture. The soft, pulpy, and luminous character of flesh; the rigid, hard, and metallic character of armour; the graceful folds and undulations of draperies, the twittering, unsteady, and luxuriant foliage of trees, with the bright yet deep-toned colour of skies, have by this mode, when practised by the best engravers, been more successfully rendered than by any other. The process of line-engraving is, first, to etch the plate in the manner already described, and afterwards to finish it with the graver and dry point. An *engraver's etching* differs from a *painter's etching* in that every part of the work has an unfinished appearance, though many engravers, especially of landscapes, carry their etchings so far as to make them very effective: engravers of historical and other figure subjects, generally, do little more than etch the outlines, and the broad shadowed masses, or colours, of the draperies; the flesh being entirely worked in with the *burin*, or graver: no definite rules can be laid down as to the extent to which the etching should be advanced ere the work of the tool commences, as scarcely two engravers adopt the same plan precisely: much must always depend on the nature of the subject. Neither would it be possible to point out in what particular way the graver should be used in the representation of any particular object: this can only be learned in the studio of the master, or by studying the works of the best engravers: as a rule it may be simply stated, that in making the incision, or line, the graver is pushed forward in the direction required, and should be held by the handle, at an angle very slightly inclined to the plane of the steel or copper plate: the action of the graver is to cut the metal clean out.

Within the last few years an instrument, called a *ruling machine*, has been brought into use for laying in flat tints in skies, buildings, and objects requiring straight, or slightly curved lines: considerable time is saved to the artist by its use, and more even tints are produced than the most skilful hand-work, generally, is able to effect; but to counterbalance these advantages, freedom is frequently sacrificed, and in printing a large number of impressions, the machine-work, unless very skilfully ruled in, is apt to wear, or to become clogged with ink, sooner than that which is graved.

Mezzotinto engraving is generally supposed to owe its origin to Colonel Ludwig von Siegen, an officer in the service of the Landgrave of Hesse; there is extant a portrait by him, in this style, of Amelia, princess of Hesse, dated 1643. Von Siegen is said to have communicated his invention to Prince Rupert, to whom many writers have assigned the credit of originating it: there are several plates executed by the Prince still in existence. It differs from every other style of engraving, both in execution and in the appearance of the impression which the plate yields: a mezzotint engraving resembles a drawing done in washes of colour, by means of a camel's-hair pencil, rather than a work executed with any sharp pointed instrument: but a pure mezzotint engraving is rarely produced in the present day, even for portraits; the advantages derived from combining line and stipple, of which we shall speak presently, with it, to express the different kinds of texture in objects, have been rendered so obvious as almost to make them necessary: this combination is termed the *mixed style*. The distinguishing excellences of mezzotint are the rich depth of its shadows, an exquisite softness, and the harmonious blending of light and shade: on the other hand, its great defect is the extreme coldness of the high lights, especially where they occur in broad masses.

The instruments used for this kind of work are, *burnishers*, *scrapers*, *shading tools*, *roulettes*, and a *cradle*, or *rocking tool*. The burnisher and scraper differ in form from those already described: the roulette is used to darken any part which may have been scraped away too much; it ought to be of different sizes: the cradle is of the same form as the shading tool, and is used for the purpose of laying grounds.

The operation of engraving in mezzotint is precisely the opposite of that adopted in all other styles: the processes in the latter are from *light* to *dark*, in the former from *dark* to *light*, and is thus effected. A plate of steel or copper is indented all over its face by the *cradle*, an instrument which somewhat resembles a chisel with a *toothed* or serrated edge, by which a *burr* is raised on every part in such quantities that if filled in with ink, and printed, the impression would exhibit a uniform mass of deep black: this operation is called *laying the ground*; it is performed by rocking the cradle to and fro, and the directions, or *ways*, as the engravers call them, are determined by a plan, or scale, that enables the engraver to pass over the plate in almost any number

of directions without repeating any one of them. When an outline of the subject has been first etched in the ordinary way before the ground is laid, the engraver proceeds to scrape away, and then burnish the highest lights, after which the next lightest parts are similarly treated, and the process is repeated after this manner till the work is finished; the deepest shades are produced from the ground that is left untouched. There is, however, no style of engraving for the execution of which it is so difficult to lay down any definite rules, for almost every engraver has his own method of working.

Chalk or *stipple* engraving, for the terms are synonymous, is extremely simple. The plate has first to be covered with the etching ground, and the subject transferred to it in the ordinary way: the outline is then laid in by means of small dots made with the stipple graver; all the darker parts are afterwards etched in dots larger and laid closer together. The work is then bitten in with the acid; and the ground being taken off, the stipple graver must again be taken up to complete the operation; the light parts and the dark are respectively produced by small and large dots laid in more or less closely together. Stipple is well adapted for, and is often used in, the representation of flesh, when all the other parts of the subject are executed in line: hence it is very frequently employed in portraiture, and in engravings from sculpture. *Chalk engraving* is simply the imitation of drawings in chalk, and is executed like stipple, only that the dots are made with less regularity, and less uniformity of size; in the present day, the two terms are generally considered as expressing the same kind of work.

Aquatint engraving, which represents a drawing in Indian-ink or bistre even more than does mezzotint, has been almost entirely superseded by lithography, and still more recently by chromo-lithography; and there seems little probability that it will ever come into fashion again. This being the case, and as any detailed description of the mode of working would, to be of any service, occupy a very considerable space, it will, doubtless, be deemed sufficient to give only a brief outline of its character and of the mode of operation; this we abbreviate from the notice of Mr. Fielding, formerly one of our most able engravers in aquatint. The process consists in pouring over a highly polished copper plate a liquid composed of resinous gum, dissolved in spirits of wine, which latter, evaporating, leaves the resin spread all over the plate in minute grains that resist the action of the aquafortis, which, however, corrodes the bare surface of the copper that is left between them: this granulated surface is called a *ground*. The ground having been obtained, the margin of the plate should be varnished over, or stopped out, and, when dry, the subject to be aquatinted must be transferred to the plate, either by tracing or drawing with a soft black-lead pencil, which may be used on the ground with nearly the same facility as paper; if the former method be adopted the tracing must be carefully fastened down to the copper by bits of wax along the upper edge. A piece of thin paper, covered on one side with lamp-black and sweet oil, is placed between the tracing and the ground, with the coloured side downwards, and every line of the subject must be passed over with the tracing point, using a moderate pressure. The tracing being finished and the paper removed, a wall of prepared wax, about three quarters of an inch high, must be put round the plate, with a large spout at one corner, to allow of the acid running off.

The plate is now ready for use; and the completion of the design is commenced by stopping out the highest lights on the edges of clouds, water, &c., with a mixture of oxide of bismuth and turpentine varnish, diluting it with spirits of turpentine till of a proper consistence to work freely. Next pour on the acid, composed of one part of strong nitrous acid and five parts of water; let it remain, according to its strength, from half a minute to a minute, then let it run off, wash the plate two or three times with clean water, and dry it carefully with a linen cloth. This process of stopping out and biting in is continued till the work is complete; each time the aquafortis is applied a fresh tint is produced, and as each part successively becomes dark enough it is stopped out; in this manner a plate is often finished with one ground bitten in ten or twelve times. We would recommend those who may desire to become thoroughly acquainted with this very interesting yet difficult mode of engraving to consult Fielding's *Art of Engraving*.

A few remarks explanatory of the method of printing steel or copper plates seem to be inseparable from the subject. The press used for the purpose consists of two cylinders or rollers of wood, supported in a strong wooden frame, and movable at their axes. One of these rollers is placed just above, and the other immediately below, the plane or table upon which the plate to be printed is laid. The upper roller is turned round by means of cogged wheels fixed to its axis. The plate being inked by a printer's inking-roller, an operation requiring great care, the paper which is intended to receive the impression is placed upon it, and covered with two or three folds of soft woollen stuff

like blanketing. These are moved along the table to the spot where the two rollers meet; and the upper one being turned by the handle fixed to the fly-wheel, the plate passes through it, conveying the impression as it moves; the print is then taken off the plate, which has to undergo the same process of inking for the next and every succeeding impression. The *proofs* of an engraved plate are always taken by the most skilful workmen in a printing establishment; in the principal houses there are generally employed from two to six men, according to the amount of business transacted, whose duty it is to print proof impressions only; they are called *provers*. A careful, steady workman is not able to print more than from 180 to 200 good ordinary impressions from a plate, the subject of which occupies about seven inches by ten inches, even in what is considered a long day's work, that is, about fourteen hours; the *prover*, from the extreme care required in inking the plate, and from the extra time occupied in wiping it, and preparing the India-paper, will do from thirty to forty, according as the subject of the plate is light or heavy. This difference in the cost of production, taking also into account that the *proofs* are worked off before the plate has become worn, even in the least degree, and that very few proofs, compared with the ordinary prints, are generally struck off, is the reason why they are sold at a price so much greater than the latter.

Notwithstanding the vast multiplication of engravings within the last few years, it is generally admitted, by those best acquainted with the present state of the art, that it is not in a healthy condition. The highest class of pictorial subjects—history, and the highest style of engraving—line, have given place to subjects of less exalted character, and to a mixed style of work, which, however effective for its especial purpose, is not pure art. The pictures by Sir E. Landseer have gained for engravings of such subjects a popularity that has driven almost everything else out of the field, and have created a taste in the public which is scarcely a matter of national congratulation. We have engravers in the country capable of executing works equal to whatever has been produced elsewhere at any time, but their talents are not called into requisition in such a way as to exhibit the art of engraving in its highest qualities. Publishers are not willing to risk their capital on works which the public cannot appreciate, and hence their windows are filled with prints, the subjects of which, however pleasing and popular, are not of a kind to elevate the taste; while the conditions under which engravers generally are compelled to work, offer but little inducement for the exercise of the powers at their command. Engraving on copper is in the present day but rarely attempted; formerly nothing else was thought of; now the demand for engraving is so great that copper, even aided by the electrotype, is insufficient to meet its requirements. In consequence of the comparatively small number of impressions which it yields, a copper-plate will seldom produce more than 500 or 600 good prints; we have known a steel, with occasionally retouching, produce more than 30,000, when well engraved, and carefully printed; very much depends on the printer, both with regard to the excellence of the impression and the durability of the plate. The public demand is for prints both large and cheap, and to obtain this result, the engraver is too often obliged to sacrifice those qualities of his art which under other circumstances his work would exhibit. Such is the state of engraving with us now. There are few, even of the best artists we have, who by their utmost efforts can earn an income equal to that of a tradesman in a small but respectable way of business. This is an evil to be deplored, for it assists to deteriorate the art by forcing the engraver to labour hard for a maintenance, instead of placing him in a position that would enable him to exalt the art and his own reputation at the same time.

A process of depositing steel upon an engraved copper-plate has recently been brought over to this country from France. M. Joubert, a French engraver long settled in England, has introduced it here; he has informed us that a copper-plate thus covered may be made to yield almost any number of impressions, for as the steel coating becomes worn it can be entirely taken off, and a new deposit laid on without injury to the engraving, and this may be done several times; M. Joubert has repeated the experiment with the most satisfactory results. He thus describes his process in a communication made to the Society of Arts, and printed in their journal:—

"If the two wires of a galvanic battery be plunged separately into a solution of iron, having ammonia for its basis, the wire of the positive pole is immediately acted upon, while that of the negative pole receives a deposit of the metal of the solution—this is the principle of the process which we have named "acierage."

"The operation takes place in this way:—By placing at the positive pole a plate or sheet of iron, and immersing it in a proper iron solution, the metal will be dissolved under the action of the battery, and will form an hydrochlorate of iron, which, being combined with the hydrochlorate of ammonia of the solution, will become a bichloride of ammonia and iron; on a copper plate being placed at the opposite pole and

likewise immersed, if the solution be properly saturated, a deposit of iron, bright and perfectly smooth, is thrown upon the copper-plate, from this principle : —

" Water being composed of hydrogen and oxygen :

" Sal ammoniac being composed of : —

" 1st. Hydrochloric acid containing chlorine and hydrogen ;

" 2nd. Ammonia, containing hydrogen, nitrogen, and oxygen :

" The water is decomposed under the galvanic action, and the oxygen fixes itself on the iron plate, forming an oxide of iron ; the acid hydrochloric of the solution acting upon this oxide becomes a hydrochlorate of iron, whilst the hydrogen precipitates itself upon the plate of the negative pole, and, unable to combine with it, comes up to the surface of the solution in bubbles.

" My invention has for its object certain means of preparing printing surfaces, whether for intaglio or surface printing, so as to give them the property of yielding a considerably greater number of impressions than they are capable of doing in their ordinary or natural state. And the invention consists in covering the printing surfaces, whether intaglio or relief, and whether of copper or other soft metal, with a very thin and uniform coating of iron, by means of electro-metallurgical processes. And the invention is applicable whether the device to be printed from be produced by engraving by hand, or by machinery, or by chemical means, and whether the surface printed from be the original, or an electrotype surface produced therefrom. I would remark that I am aware that it has been before proposed to coat type and stereotypes with a coating of copper, to enable their surfaces to print a larger number of impressions than they otherwise would do ; I therefore lay no claim to the general application of a coating of harder metal on to the surface of a softer one, but my claim to invention is confined to the application of a coating of iron by means of electricity on to copper and other metallic printing surfaces.

" In carrying out the invention I prefer to use that modification of Grove's battery known as Bunsen's, and I do so because it is desirable to have what is called an intensity arrangement. The trough I use for containing the solution of iron in which the engraved printing surface is to be immersed in order to be coated is, lined with gutta percha, and it is 45 inches long, 22 inches wide, and 32 inches deep. In proceeding to prepare for work, the trough, whether of the size above mentioned or otherwise, is filled with water in combination with hydrochlorate of ammonia (sal ammoniac) in the proportion of one thousand lbs. by weight of water to one hundred lbs. of hydrochlorate of ammonia. A plate of sheet iron, nearly as long and as deep as the trough, is attached to the positive pole of the battery and immersed in the solution. Another plate of sheet iron, about half the size of the other, is attached to the negative pole of the battery, and immersed in the solution, and when the solution has arrived at the proper condition, which will require several days, the plate of iron attached to the negative pole is removed, and the printing surface to be coated is attached to such pole, and then immersed in the bath till the required coating of iron is obtained thereto. If, on immersing the copper plate in the solution, it be not immediately coated with a bright coating of iron all over, the bath is not in a proper condition, and the copper plate is to be removed and the iron plate attached and returned into the solution. The time occupied in obtaining a proper coating of iron to a printing surface varies from a variety of causes, but a workman after some experience and by careful attention will readily know when to remove the plate from the solution ; and it is desirable to state that a copper plate should not be allowed to remain in the bath and attached to the negative pole of the battery after the bright coating of iron begins to show a blackish appearance at the edges. Immediately on taking a copper plate from the bath great care is to be observed in washing off the solution from all parts, and this I believe may be most conveniently done by causing jets of water forcibly to strike against all parts of the surface. The plate is then dried and washed with spirits of turpentine, when it is ready for being printed from in the ordinary manner.

" If an engraved copper plate be prepared by this process, instead of a comparatively limited number of impressions being obtained and the plate wearing out gradually, a very large number can be printed off without any sign of wear in the plate, the iron coating protecting it effectually ; the operation of coating can be repeated as many times as required, so that almost an unlimited number of impressions can be obtained from one plate, and that a copper one.

" This process will be found extremely valuable with regard to electrotype plates and also for photogalvanic plates, since they can be so protected as to acquire the durability of steel, and more so, for a steel plate will require repairing from time to time, these will not, but simply recoating them whenever it is found necessary ; by these means one electro copper plate has yielded more than 12,000 impressions, and was found quite unimpaired when examined minutely."—J. D.

ENGRAVING ON WOOD. The art of wood engraving is so intimately connected with that of book-printing, that it is impossible to dissever the one from the other, inasmuch as the earliest books were printed from large woodcuts, the entire page, text, and illustrations being engraved in one solid block. Hence the term "block-books" given to these ancient works. The impression from these engraved pages is generally taken in a thin ink, sometimes of a brown hue, which occasionally spreads or blots on the lines or letters; and the printing is generally supposed to have been effected by friction on the back of the damped paper laid on the inked lines; the sheets so printed were afterwards pasted back to back, and thus formed consecutive pages of the volume. Such books originated from the large wood-cuts of a devotional class, which, in the early part of the 15th century, were spread by the clergy among the common people, perhaps to counteract the evil produced by the use of playing cards, which were also printed in large sheets of cuts, and severed afterwards; but on this point typographical antiquaries are not agreed, as dates and other evidence are wanting to enable us to fix either time, or place, to these early productions. The earliest wood-cut bearing a date is that belonging to Earl Spencer, and representing St. Christopher carrying the Saviour across an arm of the sea; it has two lines of text beneath it, and the date 1423 thus expressed "millesimo cccc° xx° tercio."* The British Museum is possessed of some very early single-leaf wood-cuts: one representing Christ brought before Pilate, is executed in bold coarse outline, the figures are very large, and retain the characteristic features of the drawings seen in manuscripts of the 14th century. Another undated cut is one of those fanciful inventions which the scholastic men of that early day delighted in constructing; it is termed *Turris Sapiencie*, every stone of which is inscribed with the name of some moral virtue, the foundation buttresses being prudence, fortitude, justice, and temperance; the windows which give it internal light being discretion, religion, devotion, and contemplation. Another representing the seven ages of man, is supposed to be a work of the middle of the 15th century. It was found pasted inside the covers of an old book, a practice which has preserved many specimens of old engraving which would else have been lost. On the opposite cover is a fragment of another large cut, representing the Virgin with St. Joachim and St. Anne. The St. Christopher above named was discovered in the cover of a volume in the conventual library at Buxheim, in Suabia. All these old wood-cuts, as well as the block books, are generally daubed with flat tints of coarse colour, supposed to have been done with stencil plates, such as the card painters used on some occasions; but evidently rudely executed by hand in others. They are all precisely of the kind to attract the uneducated eye; and to this day similar coarse prints are used by the clergy to aid the devotions of the peasants of the Germanic nations.

The most celebrated of the block books is that termed the *Biblia Pauperum*. Each page is divided by architectural compartments into three subjects, from the Old and New Testament, selected to form "parallel passages" of sacred writ; above and below are other compartments with heads of the prophets, and in the intervening spaces, or upon scrolls, are explanatory inscriptions. The page measures 10 inches by 7½, and is one of the most elaborate works of its class; but it exhibits very small claims to attention as a specimen of art, certainly less than the *Cantica Canticorum*, each page of which is divided horizontally into two pictures, with slight descriptive lines on scrolls; or the *Apocalypsis Sancti Johannes*, which is similarly arranged, and in both of which we occasionally find much power of drawing and ability of grouping. The dates of these books can only be conjecturally given, but they are probably contemporary with the St. Christopher, or but a few years later. Judging from general characteristics the *Apocalypse* seems to be the earliest. The figures are executed entirely in outline, with no attempt at shadows, which appear sparingly on the St. Christopher, and are very freely introduced in the *Canticles*, and still more abundantly in the *Biblia Pauperum*. These effects are always produced by a series of short lines laid parallel to each other, nor is any attempt made to enrich the meagre character of the work by crossing the lines, as in more modern engraving. The debate, which has excited so many historians as to the place where printing first had birth, has included many doubts concerning the country where these old block-books were fabricated; but from the armorial bearings which appear on the shields of some figures in the *Canticles*, Germany seems to be the country where that series was designed†; probably

* Much interest was excited some few years ago by the discovery of a cut in the library at Brussels apparently bearing an earlier date; but strict investigation has since proved that one of the C's in the date has been omitted; this makes just one hundred years difference in its age. But the date thus altered is quite in accordance with the general character of the design and execution of the cut, which, on the contrary, do not at all agree with the earlier date originally assigned to it.

† Among them is the double-headed eagle of Austria, the black eagle of Germany, the three crowns of Cologne, the cross-keys of Ratisbon, the arms of Wurtemberg, Nymphenburg, and Alsace.

Flanders or Holland may claim the *Biblia Pauperum*, which does not bear equal traces of refinement in art. The *Speculum Humanæ Salvationis* has been claimed for Laurence Coster of Haarlem. This book was a combination of block-book and movable type, having long cuts across the top of each page, divided by columns into two subjects, with moveable types beneath. It is not unusual to meet with woodcut pages of type alone at this period; and books with such pages, or with the addition of wood cuts, were produced by the old engravers after the invention of movable types; but, as metal-cast letters speedily usurped the place of the wooden ones, the wood engravers seem to have soon confined themselves to the pictorial branch of the art.

The love of pictured illustrations of narrative history gave a permanence to the art of wood engraving, and the works printed in Italy, as well as those introduced into England by Caxton, were adorned with cuts. They are, however, of the rudest kind, with broad heavy lines, and were most probably produced from coarse pen drawings made on the surface of the wood, and mechanically cut by the engraver. Toward the close of the fifteenth century "cross hatching" (as lines of shadow crossing each other are technically termed) is first seen, and in the Nuremburg Chronicle, 1493, they are freely used. The designers and engravers of these cuts, perceiving the effect, which may be so readily obtained in wood engraving, by leaving the wood untouched with the graver for solid masses of shadow, have availed themselves of it, and given stronger effect to their cuts thereby. Michael Wohlgemuth and William Pleydenwurff were the designers employed; the former artist was the master of Albert Durer, who ultimately raised wood engraving to the highest point of excellence.

Durer's first great work was a series of sixteen large cuts illustrative of the Apocalypse. They were published in 1498, and attracted great attention from the vigour and strange originality of their design, and the artistic character of their treatment. In 1511 another series of cuts was published at Nuremberg by Durer, illustrative of the Apocryphal Life of the Virgin. They evidence the great improvement which the artist had made during the interval, and are certainly the finest wood cuts which had ever been executed up to that period; but they are eclipsed by the series of eleven large cuts published soon after, representing scenes in the Passion of Christ; and which may be fairly considered triumphs of the art of wood-engraving, unsurpassed in design and execution by any successors. The art had now become appreciated wherever it was known, and a host of wood engravers found employ in Nuremberg, cutting the designs of Durer, Hans Burgmair, Hans Schanfelein, and other artists; who found no lack of patronage in the old imperial city, for the Emperor Maximilian I., extensively employed them in various works illustrative of his real or fancied exploits.*

So important was this royal patronage, that the engravers set no bounds to the size of the works they attempted, and hit upon the plan of joining one block of wood to another, until in the engraving representing the triumphal arch in honour of this emperor, a wood-cut was completed in this way, measuring ten feet by nine. The size is, however, not its only claim to attention, for it is throughout designed and engraved with the utmost care and beauty.

In all these cuts of the great masters of the art of wood-engraving, we only find the name of the designer recorded; thus, Durer, and others of his era, whose names occur on cuts, were the designers and draughtsmen on the wood; but the engraver was considered in the light of a mechanician, and, except in a very few instances, his name was not displayed. To fully understand this, it is necessary here to explain the whole process of wood engraving at this time. A block of wood being prepared from a perpendicular cutting of pear-tree, upon the surface was made a drawing, in which every line was delineated with pencil or reed-pen, exactly as the cut was ultimately to appear; the intervening spaces of plain wood between every line were then cut away; and in this manual dexterity consisted the whole merit of the engraver. The abundance of cross-hatching so constantly found in old wood cuts, is explained by the fact of this being the easiest and best mode for the draughtsman to employ in getting his effects of light and shade; the extreme labour it involves to the engraver not being considered; but when it is understood that each minute space has to be cut down from each angle of the lines, and the centre entirely cleared out, some idea may be formed of the labour required, when thousands of such squares occur on some of Durer's large cuts, independent of other work. The backs of some of these old blocks, particularly those in the Triumphs of Maximilian, are marked with the names of the engravers, and there is proof that women practised the art; but it is not at all likely

* Such were the adventures of the Knight Thuerdank, under which form the emperor was figured; "The Wise King," an equally flattering picture of his early education and actions; and the magnificent series of cuts, known as "The Triumphs of Maximilian."

that the artists who designed, and drew upon the wood these designs, went through the merely mechanical labour of engraving them.

The great impetus thus given to wood engraving*, kept it prominently before the world during the whole of the sixteenth century, when the presses of the continent continually brought forth a series of volumes remarkable for the beauty of the cuts by which they were illustrated. This practice of the book-trade gave rise to a series of artists known as "the little masters" of the German school, from the small size of their works; among whom the principal who connected themselves with engraving on wood were Virgil Solis, Henry Aldegraver, the two Behaims, Lucas Cranach, Urse Graff, Albert Altdorffer, Jost Ammon, and Solomon Bernard.

In Italy, Ugo da Carpi practised with success, from the year 1518, the art of engraving on wood imitations of tinted drawings; an art which originated with the Germans, but which he much enlarged and improved. It consisted in a series of blocks cut to imitate patches of colour, and made to print over each other in gradations of tint, until the chiaroscuro of a drawing was secured; then the coarser and bolder lines defining the whole design were printed over all, and a capital imitation effected of the bold cartoons, consisting of vivid outline and broad washes of tint, used as first sketches for their pictures and frescoes by the artists of that era.

A perfect rage for book illustration seems to have beset the printers soon after the death of Durer. The most prolific artists who supplied their wants, were Jost Ammon and Solomon Bernard: the former executed a multitude of designs on every imaginable subject; the latter, equally prolific, devoted himself chiefly to the illustration of sacred or classic literature. The greatest publishers of such books were Sigismond Feyeraband, of Frankfort-on-the-Maine; Jean de Tournes, and Trechsel, of Lyons; and Plantyn, of Antwerp. From their presses issued a series of small volumes, which can only come under the generic title of "picture books;" for they were got up for the sake of exhibiting the favourite art of wood-engraving, and only contain a few descriptive lines of type beneath each cut. The cuts executed by Ammon are all remarkable for correctness of drawing and vigorous effect; those of Bernard are less scholastically correct, but contain more evidence of grace and fancy. The designs of these artists abound in books published between 1550 and 1580; but the most admirable series were executed in a little volume published at Lyons, in 1538, without the name of draughtsman or engraver, the *Simulachres de la Mort*, known among bibliographers as the "Lyon's *Dance of Death*," a collection of cuts which, for minute beauty and perfection of design and execution, are completely unrivalled, and have not been equalled by any modern copyist.† This was the Augustan age of book-illustration, which flourished in popular favour until the close of the sixteenth century, when a minute *tameness*, in contradistinction to the *vigour* of the earlier engravers, began to appear, and reached its culmination in such cuts as were given in Nicolay's "Travels in Turkey" (Antwerp, 1576).

Titian is said to have furnished designs for various woodcuts, particularly the series of Costumes published at Venice in 1590; and a very large coarse cut of the Destruction of Pharaoh and his host, more than four feet long, is said to have been one among many of uncommon size executed from his designs, they were printed on separate blocks, and then pasted together in the manner of wall-papers. One representing the sacrifice of Abraham is remarkable for the variously tinted inks in which it is printed to exhibit gradations of distance.

Wood-engraving, in the early part of the seventeenth century, had sunk from its high estate. The last great artist who had employed himself in connection with the art was Hans Holbein, and we do not find a great name again conjoined with it until the middle of that century, when Rubens employed Jeghers, of Antwerp, to engrave some of his drawings on wood. The generality of woodcuts in books of this era, rival in coarseness the older block-books; the wood-engravers seem to have sunk into mechanics, unassisted by good artists to furnish them with drawings. The art had become vulgarised, its profession a trade, and the demand and supply scarcely better than the requirements of the ballad printer desired. They were ancillary to the commonest uses of the press, and all art speedily vanished from the cuts manufactured probably at a very cheap rate for temporary use. Of this kind are the

* Durer's engravings were so exceedingly popular, that they found their way all over Europe. Raphael admired them in Rome, and was induced to perpetuate his own designs by employing Marc Antonio Raimondi to engrave them on metal under his own superintendence. So originated the modern print trade. Durer's designs were so much in request, that Lucas van Leyden imitated them on copper, for sale to such persons as could not perceive the great difference between the vigorous originals, and his tame and disagreeable copies. Durer was ultimately obliged to apply for legal restrictions against these piracies.

† The designs have been popularly ascribed to Holbein, and, apparently, with reason. An artist named Hans Lutzelburgher, of Basle, has been conjectured to have been the engraver, from the initials H. L. on one of them. By this time it had become usual to append the initials of engravers to woodcuts, as well as those of the designers.

cuts sprinkled through the English books of the time of James and Charles I. It is possible that the printers were supplied with them from Germany and Flanders. It was customary to use woodcuts repeatedly, particularly if merely ornamental; in this way initial letters were reproduced as the stock in trade of the printing-office*; and even scenes of adventure, adopted unscrupulously for other events, to which there was the slightest general resemblance.† The names of these "wood-cutters" have not descended to our time; their works are widely scattered over general literature, and it is not until the middle of the century that we meet with any instance of an attempt to arrest the downward progress of the art. Then, as we have previously noted, Rubens, probably anxious to rival Durer, engaged Christopher Jegher, of Antwerp, to execute, under his own superintendence and at his expense, a series of large drawings made by himself upon the wood. They differ from the style of the earlier masters, and frequently have a confused blotted look in the lines, which produce deep shadows; they possess, however, all that boldness and vigour of treatment for which the great Flemish painter was so deservedly celebrated; but the engraving is coarse and mechanical. Rubens appears to have felt this, and sometimes a tinted block is added over all, with high lights cut upon it, to give softness and brightness to the whole; an idea he may have adopted from the engravers of Italy who succeeded Ugo da Carpi (among whom may be honourably mentioned Andreas Andreani, of Mantua, born 1540, died 1620), or from the designs of Lalleman engraved by Businck, which were nearly contemporaneous in France.

Though "fallen from its high estate," the art never sank into complete decay, either in England or upon the continent; there were always a few who followed the profession, and aided the printer with such cuts and diagrams as he might require. The family of the Jeghers practised in Antwerp until the end of the century; a clever series of woodcuts illustrative of the service of the Mass was published at Ghent, and executed by Kraaft in 1732. In France, the family of Le Sueur were employed through three generations by booksellers; the last, Nicholas, died in 1764; while Papillon, the author of a *Traité de la Gravure en Bois*, had practised the art from the commencement of the century until 1770, and had been patronised so extensively by the booksellers of France and Holland that he counts his cuts by the thousand. In England, E. Kirkhall executed cuts for books, and from 1722 to 1724 a series of 12 block-prints, in imitation of Ugo da Carpi's work already alluded to; in this latter style he produced a greater pupil in J. Jackson, who very successfully copied some of the great works of Titian, Paul Veronese, and others, during the years 1738 to 1742; at this time he resided in Venice, after a short sojourn in Paris, where he was occasionally employed as a wood-engraver. Many cuts scattered through English books about the same period bear the initials of F. H. for Francis Hoffman, whose name is engraved in full on a tail-piece, representing cupids surrounding a lighted altar, to be seen in the first edition of *Gulliver's Travels*, 1726, vol. ii. p. 47. An engraver named Lister executed some cuts of a much better character than usual about 1760, particularly those in the *Oxford Sausage;* and in Sir John Hawkins's *History of Music* are some of the largest and most ambitious cuts at that time attempted anywhere. They were engraved by T. Hodgson. Three other persons named respectively, W. Pennock, S. Watts, and H. Cole, occasionally devoted themselves to wood-engraving, which seems to have been practised by such copper-plate engravers as devoted themselves to "general work" for the printing trade or the public, and who varied their labours by occasionally engraving shop-bills or door-plates.

There is one great change in the cuts produced during this period, the result of a different style of drawing made for the wood-engravers, and which discarded cross-hatching and its consequent tedious labour, for a tinted or washed drawing which could be cut into a series of lines by the tool, expressing the varied tints more simply and readily. The art of "lowering" or scraping down to a lower level various parts of a cut that should appear light, and so assist the press in its labours, was also practised, and the harder wood of the box tree used. Such was the state of the art when a Northumbrian peasant boy was destined to appear, again draw universal attention to the neglected profession, and found the modern school of wood engraving.

Thomas Bewick was the son of parents engaged in a colliery, who lived at Cherryburn twelve miles west of Newcastle-on-Tyne; he was born in 1753 and passed his

* In the old printing office of Plantyn at Antwerp, is still preserved a large quantity of woodcuts, originally engraved for the books he issued at the end of the 16th century, particularly the emblems of Alciati and Sambuco.

† The number of impressions a woodcut will yield has never yet been established. The elasticity of wood gives it a great advantage over metal in press-printing; and while copper and steel wear out, wood shows little sign of wear; many thousands of impressions may be taken by a carefully moderate printer without injuring a woodcut. As an instance with what impunity a bad printer may use a coarse woodcut, may be mentioned the fact, that the ballad printers of the middle of the last century occasionally used cuts that had been engraved in the reign of Charles I., and had headed popular ballads for more than 100 years.

early years helping his father's labour. His leisure hours were earnestly devoted to the small amount of knowledge a village school could impart; but as a strong love for nature, and for its imitation, soon developed itself in the boy, his father determined to apprentice him to an engraver of Newcastle, Mr. R. Beilby, whose work was of that "general" kind undertaken in a busy country town. There he occasionally engraved initials on tea-spoons or names on door plates, until, in the second year of his apprenticeship, his master received an application from Dr. Hutton for wood-cut diagrams, such as were then executed in London, to illustrate his treatise on mensuration. Beilby knew that young Bewick had been making some attempts in this style and he encouraged him to persevere; he did so, and Hutton's book was published in 1770 with Bewick's cuts. The young engraver had many difficulties to contend against, and had even to construct his own tools; among the rest, a double-pointed graver to enable him to cut both sides of a line at once, and so ensure its equal thickness throughout. In 1775, he executed a cut and sent it to the Society of Arts, in London, who awarded him a medal; and in the following year he visited London, and was employed by Hodgson, whom we have already noted as the engraver of the cuts in Hawkins's *History of Music*; as well as by H. Cole. There need be little doubt that this visit to the London wood-engravers was useful to Bewick, for he must have become by that means acquainted with the usual mode of practising the art, the proper kinds of tools used, and the various things which make the mechanical part of the profession; but he had fortunately formed a style of his own, so very original, and based so firmly on the study of nature, that wood-engraving in his hands became an art presenting many novel and attractive features never visible before. The wood-engravers from the days of Durer, or from the first invention of the art, depended slavishly on the drawings made upon the wood, and did little more than cut away the interstices; but Bewick cut out of the wood a vast deal of that which no draughtsman could so draw; for with the aid of a slightly tinted drawing, he would cut the foliage of trees, the plumage of birds, the texture of animals, or small figures and birds, by the graving tool alone. His dextrous hand was guided by a perfect knowledge of nature, and every line he cut expressed drawing; in this was his great distinction over all other wood engravers; he cut his pictures out of the wood, the others cut the wood out of the pictures.

Bewick disliked London, and speedily returned to his native place. His first work was an illustrated edition of Gay's Fables, published in 1779 by T. Saint, a printer of Newcastle, much engaged in the publication of children's books, and such as the travelling chapmen carried in their packs for the edification of the villagers. These cuts bear the earliest traces of that accurate delineation of nature, and minute truthfulness of expression, which ultimately gave his works universal renown. The wild plants and grasses, however minute they are cut, can always be distinguished by the naturalist; the proper foliage of every tree is truthfully cut by his graver; the birds and insects, however minute, are perfect in drawing; and the general effect of his wood-cuts artistically powerful. As he fully felt the value of leaving the wood itself to express solid shadow, he had not the timidity which imagines labour to be necessary to success. The little cut of the Fox and the Bramble in this volume is a good illustration of Bewick's mode. Every leaf of the bramble is cut out, white upon black, with the most truthful power of drawing; the spines on the stem of the bramble are visible to the eye; the fern beside it is similarly expressed by cutting the form of its foliage with the most perfect freedom upon the solid block of wood. Each bush has its distinctive leaf. The dogs in the distance are similarly cut out by the graver on a tinted ground; and the few lines which cover the body of the fox entangled in the bramble, express its texture with a spirit which no mere cutting of a drawing placed on wood by a professional draughtsman could ever give. Bewick's cuts are sometimes termed *coarse*, but no elaboration of labour will elevate the costliest woodcut above these works, for which Bewick obtained but nine shillings each; unless drawing can be expressed by the engraver as perfectly as Bewick could express it.

Assisted by his brother John, the Newcastle engraver issued a series of works devoted to natural history; the best being the *History of British Birds*. Here Bewick's knowledge of nature, and power of expression by means of his graver shone forth conspicuously. His books became equally celebrated for the humorous tail-pieces he occasionally introduced redolent of whim and original genius. He laboured steadfastly at his art to a good old age. His brother John left Newcastle to reside in London, where he was much employed, but a pulmonary complaint killed him at the early age of thirty-five. He died in 1795. Thomas Bewick lived to the advanced age of seventy-five. He died in 1828, having worked upon a large woodcut only a few days before his death.

The pupils educated by Bewick were few. The best were Charlton Nesbit, Luke

Clennell, William Harvey, and John Jackson. Nesbit settled in London, and was extensively employed during a long life. Clennell after a while, devoted himself to painting. Harvey turned his attention to drawing on wood, and his designs for book illustration may be numbered by the thousand; his best are in Lane's edition of the *Arabian Nights' Entertainments*. Jackson was greatly employed by the publisher of the latter work, Mr. Charles Knight, particularly on the best cuts in the once-famed *Penny Magazine*.

At the early part of the present century, Mr. Robert Branston founded a London school of wood-engravers, of which he was the head. His style was peculiar, unlike Bewick's, though like him he was self-taught. His cuts have more refinement, but less knowledge of nature; his best pupil was John Thompson, who combines in his best cuts, the refined knowledge of light and shade, with much of Bewick's power of expressing drawing. Samuel Williams was one of the few modern engravers, who made his own drawings upon the wood, and he produced very brilliant effects by frequently leaving the wood in solid masses of black. Drawings for wood engravers were at this time chiefly supplied by artists who devoted themselves to that particular branch of the art; and knew how to design their compositions so that they should best display the peculiarities of wood-engraved effects. Thurston, Craig, and Harvey were the principal artists so engaged.

A large number of wood-engravers, the pupils of the Newcastle and London *ateliers*, helped to supply the booksellers at home and abroad for a considerable number of years. It was the custom, some twenty years ago, for the foreign booksellers, particularly in Paris, to send the blocks across the channel to English engravers to execute; this led ultimately to several settling on the continent, particularly in France and Germany. The French publishers always sent the wood block with the drawing carefully executed on its surface, by a native artist. These drawings were always elaborately executed in pencil, greatly resembling etchings; little was consequently left for the engraver to do, but follow the lines and cut away the spaces; patience hence became the chief virtue of the wood engraver; and it was ultimately found that its exercise produced so certain an effect, that apprentices knowing nothing of art might aid in thus working out good engravings; and the old style of tinted drawing on wood was discarded for this "fac-simile" work; the best draughtsmen among the French and German artists having willingly furnished these drawings, English artists of a higher grade were induced to draw on wood, but they occasionally failed from not clearly understanding the peculiar effects their work should produce, and the characteristics of the art. Generally speaking, wood engravers prefer cutting from the drawings of professional draughtsmen on wood; who generally execute their work with such elaborate precision, that the engraver has nothing more to do than follow their lines; this, however, has made mere mechanism of much modern wood-engraving; and many expensive cuts exhibiting pencilling in crossed and re-crossed lines, occupying wearisome labour, and costing many ill-bestowed sovereigns, can only be classed with such "art" as is devoted to engraving the Lord's Prayer in the compass of a silver penny; and merely produces the same general effect that Bewick would have obtained in a few bold lines.

The great difference between ancient and modern wood engraving consists in this very boldness; and the practice of the art was essentially different in the sixteenth and eighteenth centuries. The old wood engravers cut on large blocks of soft wood, such as pear-tree, the way of the grain; the moderns, on small blocks of the hardest wood they can obtain — the turkey box, and across the grain. The old engravers cut the work downwards with small knives or gouges; the moderns use gravers of various widths to cut out the spaces between fine lines, and broader chisels or gouges to clear away the broad spaces of white. Wood engraving is the exact opposite to copper-plate engraving in the mode by which the lines of engraving are produced. The copper-plate engraver produces his lines by cutting *into* the metal at once, the wood engraver produces his lines in relief cut *out* of the block of wood; every line he engraves has to be cut by a double operation, by slicing away the wood on each side of it; for though it is recorded that Bewick invented a double cutting fork-shaped graver to cut away both sides of a line at once, no such tool has ever since been used in the profession.

In order to make the whole process of wood engraving clear to the reader, we will now simply describe the production of a wood cut from the time it leaves the timber-merchant, until it is fit for the hands of the printer. The log of box is cut into transverse slices, ¾ of an inch in depth, in order that the face of the cut may be on a level with the surface of the printer's type, and receive the same amount of pressure; the block is then allowed to remain some time to dry, and the longer it is allowed to do so the better, as it prevents accidents by warping and splitting, which sometimes happen after the cut is executed if the wood is too green. The slice is ultimately trimmed into a square block, and if the cut be large, it is made in various

pieces strongly clamped and screwed together; and this enables engravers to get large cuts done in an incredibly short space of time, by putting the various pieces into different engravers' hands, and then screwing the whole together. The upper surface of the wood is carefully prepared so that no inequalities may appear upon it, and it is then consigned to the draughtsman to receive the drawing. He covers the surface with a light coat of flake white mixed with weak gum-water, and the thinner this coat the better for the engraver. The French draughtsmen use an abundance of flake white, but this is liable to make the drawing rub out under the engraver's hands, or deceive him as to the depth of the line he is cutting in the wood. The old drawings of the era of Durer seem to have been carefully drawn with pen and ink on the wood; but the modern drawing being very finely drawn with the pencil or silver point is obliterated easily, and there is no mode of "setting" or securing it. To obviate this danger the wood-engraver covers the block with paper, and tears out a small piece the size of a shilling to work through, occasionally removing the paper to study the general effect, in damp and wintry weather he sometimes wears a shade over the mouth to hinder the breath from settling on the block. It is now his business to produce in relief the whole of the drawing; with a great variety of tools he cuts away the spaces, however minute, between each of the pencil lines; and should there be tints washed on the drawing to represent sky and water, he cuts such parts of the block into a series of close lines, which will, as near as he can judge, print the same gradation of tint. Should he find he has not done so completely, he can re-enter each line with a broader tool, cutting away a small shaving, thus reducing their width and consequently their colour. Should he make some fatal error that cannot be otherwise rectified, he can cut out the part in the wood, and wedge a plug of fresh wood in the place, when that part of the block can be re-engraved. An error of this sort in a wood-cut is a very troublesome thing; in copper engraving it is scarcely any trouble; a blow with a hammer on the back will obliterate the error on the face, and produce a new surface; but in wood, the surface is cut entirely away except where the lines occur, and it is necessary to cut it deep enough not to touch the paper as it is squeezed through the press upon the lines in printing. To aid the general effect of a cut, it is sometimes usual to lower the surface of the block before the engraving is executed in such parts as should appear light and delicate; they thus receive a mere touch of the paper in the press, the darker parts receiving the whole pressure and coming out with double brilliancy. When careful printing is bestowed on cuts, it is sometimes usual to ensure this good effect, by laying thin pieces of card or paper upon the tympan, of the shape needed to secure pressure on dark parts only.

Wood engraving, as a most useful adjunct to the author, must always command a certain amount of patronage. In works like the present, the author is greatly aided by a diagram, which can more clearly explain his meaning than a page of letter-press; and it can be set up and printed with the type, a mode which no other style of art can rival in simplicity and cheapness. The taste for elaborately executed wood engravings may again decrease, as we find it did for nearly two centuries; but it was never a lost art, and never will be, owing to the practical advantages we speak of, unless it be superseded by some simpler mode of doing the same thing hitherto undiscovered. The number of persons who practise wood engraving in London alone, at present is more than 200, and when we consider the quantity done in the great cities of the continent, and the large amount of book illustration in constant demand; the creative power of one single genius — Thomas Bewick — shines forth in greater vigour than ever. — F. W. F.

ENTRESOL. A floor between other floors; a low set of apartments placed above the first floor. The Quadrant, Regent Street, has a good example of the entresol. In Italy the term *Mazzanino*, or little middle floor, is used to indicate the same arrangement.

ENVELOPES. The manufacture of envelopes has so largely increased, that the old method of folding them by means of a "*bone folding stick*," although a good workman could thus produce 3000 a day, was not capable of meeting the demand; hence the attention of several was turned to the construction of machines for folding them. Amongst the most successful are the following.

Envelope folding.—In the envelope folding machine of Messrs. De la Rue & Co., each piece of paper, previously cut by a fly press into the proper form for making an envelope (and having the emblematical stamp or wafer upon it), is laid by the attendant on a square or rectangular metal frame or box, formed with a short projecting piece at each corner, to serves as guides to the paper, and furnished with a movable bottom, which rests on helical springs. A presser at the end of a curved compound arm (which moves in a vertical plane, then descends, and presses the paper down into the box, — the bottom thereof yielding to the pressure; and thereby the four ends or flaps of the piece of paper

are caused to fly up; the presser may be said to consist of a rectangular metal frame, the ends of which are attached to the outer part of the curved arm, and the sides thereof to the inner portion of the arm; so that the ends and sides of the presser can move independently of each other. The ends of the presser then rise, leaving the two sides of it still holding down the paper; two little lappet pieces next fold over the two side flaps of the envelope; and immediately a horizontal arm advances, carrying a V-shaped piece charged with adhesive matter or cement (from a saturated endless band), and applies the same to the two flaps. A third lappet presses down the third flap of the envelope upon the two cemented flaps, and thereby causes it to adhere thereto; and then a pressing-piece, of the same size as the finished envelope, folds over the last flap and presses the whole flat. The final operation is to remove the envelope, and this is effected by a pair of metal fingers, with indiarubber ends, which descend upon the envelope, and, moving sideways, draw the envelope off the bottom of the box (the pressing piece having moved away and the bottom of the box risen to the level of the platform of the machine) on to a slowly moving endless band, which gradually carries the finished envelopes away. A fresh piece of paper is laid upon the box or frame, and the above operations are repeated. This machine makes at the rate of 2700 envelopes per hour.

Another machine for the same object, was invented by Mr. A. Remond, of Birmingham, and is that employed by Messrs. Dickinson & Co. The distinguishing feature of this arrangement is the employment of atmospheric pressure to feed in the paper which is to form the envelope, and to deflect the flaps of the envelope into inclined positions, to facilitate the action of a plunger, which descends to complete the folding. The pieces of paper, cut to the proper form, are laid on a platform, which is furnished with a pin at each corner, to enter the notches in the pieces of paper, and retain them in their proper position, and such platform is caused alternately to rise and bring the upper piece of paper in contact with the instrument that feeds the folding part of the machine, and then to descend until a fresh piece is to be removed. The feeding instrument consists of a horizontal hollow arm, with two holes in the under side, and having a reciprocating movement. When it moves over the upper piece of paper on the platform, a partial vacuum is produced within it, by a suitable exhausting apparatus, and the paper is thereby caused to adhere to it at the holes in its under surface by the pressure of the atmosphere. The instrument carries the paper over a rectangular recess or box; and then, the vacuum within it being destroyed, it deposits the paper between four pins, fixed at the angles of the box, and returns for another piece of paper. As the paper lies on the top of the box, the flap which will be undermost in the finished envelope, is pressed by a small bar or presser on to the upper edge of two angular feeders, communicating with a reservoir of cement or adhesive matter, and thereby becomes coated with cement; and at the same time, the outermost or seal flap may be stamped with any required device, by dies, on the other side of the machine. A rectangular frame or plunger now descends and carries the paper down into the box; the plunger rises, leaving the flaps of the envelope upright; streams of air, issuing from a slot in each side of the box, then cause the flaps to incline inwards: and the folding is completed by the plunger again descending; the interior and under surface of such plunger being formed with projecting parts, suitable for causing the several flaps to fold in proper superposition. The bottom of the box (which is hinged) opens, and discharges the envelope down a shoot on to a table below; the feeding instrument then brings forward another piece of paper; and a repetition of the above movements takes place.

EPSOM SALTS. A sulphate of magnesia, consisting of magnesia 16·26, sulphuric acid 32·52, water 51·22. It derives its name from a mineral spring containing the salt at Epsom. It is largely manufactured. See DOLOMITE.

EQUISETUM. *Horsetails.* A family and genus of acotyledonous plants. See DUTCH RUSH.

EQUIVALENTS, CHEMICAL. By this term is understood the proportions in which substances combine with each other to form definite compounds. These proportions are referred to the common standard, hydrogen, which is taken as unity. The limits of this work preclude the possibility of entering into the history of the steps by which the doctrine of equivalents was gradually developed; but it is proper that we should indicate some of the methods by which the equivalents of elements and compounds are ascertained and demonstrated to be correct. But before proceeding it is necessary to define the term equivalent. This is not easy to do, because the theoretical ideas of all chemists are not the same. Suppose, for example, the constitution of water were to be taken as the starting point. On submitting it to the action of the pile, it is immediately observed that the ratio of the two gases evolved is as 1 to 2. One chemist will at once assume that water is a simple binary compound of one equivalent of each of its constituents. But this involves the assumption that the gaseous volume of the equivalent of hydrogen is twice that of

oxygen. The other chemist assuming that one volume of a gas represents an equivalent, considers water to be a ternary compound having the formula H^2O. It is plain that the atom of hydrogen will have only half the value on the second hypothesis that it will on the first, or, what comes to the same thing, the atom of oxygen will be twice as great. If, with some chemists, we consider the volumes of the gases to represent atoms or equivalents, then, water consisting of two volumes of hydrogen and one volume of oxygen, and as by weight water contains 8 parts of oxygen to 1 part of hydrogen, it is plain that 8 parts of oxygen by weight will represent one equivalent, and 1 part by weight of hydrogen will represent 2 equivalents. Consequently 1 equivalent of hydrogen will weigh ·5. But to avoid fractional numbers it will (on these assumptions) be more convenient to write the equivalent of hydrogen = 1, and oxygen 16. In this country it is usual to consider the atom of hydrogen as occupying twice the space in the gaseous state of that of oxygen. The atomic weights being, therefore, oxygen 8 and hydrogen 1.

We have said that it is by no means easy to define an equivalent. The difficulty arises not merely from the different aspects under which theoretical chemists regard the elements and their compounds, but also from the practical difficulties attending the determination of the true constitution of some substances. Thus the equivalent of bismuth is assumed by some to be 71 and by others 213; the oxide in the one case becomes BiO, in the other BiO^3. The first equivalent being only one-third as great as the second. But, it is to be observed, the variations in the theoretical views of chemists are of no consequence, so long as we clearly comprehend the nature of those variations. The *relative* values or proportions are the same in all cases. It is, in fact, somewhat the same as if one class regarded the avoirdupois pound as made up of sixteen ounces, each ounce weighing 437·5 grains, and the other considered it as consisting of eight ounces, each ounce containing 875·0 grains.

In order to clearly understand the nature of the equivalents as received in this country, it is necessary to remember that there are three relations of volume amongst gases, namely, one, two, and four volumes. The first relation applies solely to elementary gases. The two others apply to elements and compounds. [It is true that the vapour densities of pentachloride of phosphorus, chloride of ammonium, and, perhaps, one or two other substances, appear to differ from this rule, but it is probable that, like sulphur, the vapour densities require to be determined under special conditions of temperature or pressure.] In the table of equivalents the density of the vapours of those substances which are capable of assuming the gaseous states are so placed that the number obtained by experiment may be compared with that deduced from theoretical considerations. In the following table the vapour volumes or combining measures of some of the more important elements are given. We shall see presently the practical value of the information contained in it.

Element.	Combining Measure.	Element.	Combining Measure.
Hydrogen	two volumes.	Oxygen	one volume.
Chlorine	do.	Sulphur	do.
Bromine	do.	Selenium	do.
Iodine	do.	Phosphorus	do.
Fluorine (*hypothetical*)	do.	Arsenic	do.
Nitrogen	do.	Carbon	do.

It must be remembered that all volatile compounds possess four volume formulæ, except a few, which in this country are always written as if possessing a condensation to two volumes; such are carbonic acid, carbonic oxide, sulphurous acid, &c. With the above information it will be easy for any person to calculate the density of any vapour or gas by the aid of the following directions.

To obtain the density of any vapour or gas having a condensation to four volumes, such as most organic or inorganic compounds.—Multiply half the density of hydrogen by the atomic weight of the vapour or gas. EXAMPLE:—Find the density of the vapour of hydrobromic acid. The atomic weight of hydrobromic acid is 81. The density of hydrogen is 0·0692, half of which is 0·0346. Then 0·0346 × 81 = 2·8026. Experiment gave 2·73.

To obtain the density of any vapour or gas having a condensation to two volumes.—Multiply the density of hydrogen by the atomic weight of the gas or vapour. EXAMPLE:—Find the density of chlorine gas. The atomic weight of chlorine being 35·5, and the density of hydrogen 0·0692, we have by the rule, 0·0692 × 35·5 = 2·4566. The density by experiment is 2·44.

To obtain the density of any vapour, or gas, having a condensation to one volume.—Multiply twice the density of hydrogen by the atomic weight of the gas or vapour. EXAMPLE:—Find the density of the vapour of oxygen. The atomic weight of

oxygen being 8, and twice the density of hydrogen being 0·1384, we have 0·1384 × 8 = 1·1072. Experiment has yielded 1·1056.

The above methods of calculating the densities of vapours and gases are those always employed by the writer of this article, and will be found incomparably shorter and more convenient than any other.

It is perfectly plain that, by a simple inversion of the above rules, it is equally easy from the known density of a gas or vapour to calculate its atomic weight. Nevertheless, for the sake of those who are unaccustomed to calculations of this kind, we append the following rules.

To calculate the atomic weight of any gas or vapour having a condensation to four volumes.—Divide the density of the gas by half the density of hydrogen. EXAMPLE: — Find the atomic weight of hydrobromic acid gas, the density of which is 2·8026; $\frac{2·8026}{0·0346} = 81·000$.

To calculate the atomic weight of any gas or vapour having a condensation to two volumes.—Divide the density of the gas by the density of hydrogen.

To calculate the atomic weight of any gas or vapour having a condensation to one volume.—Divide the density of the gas by twice the density of hydrogen.

It is plain then that if we are in possession of the atomic weight and vapour volume of any substance, it is easy to determine the density of its vapour or gas. Also, that having the density of the vapour and the vapour volume, it is easy to calculate the atomic weight. If we consider for an instant what is meant by the term density of a vapour or gas, it will appear equally easy to find, from the density of the gas, the weight of 100 cubic inches at the standard temperature and pressure. By the density of a gas is meant the number expressing how much it is heavier or lighter, bulk for bulk, than air. If, therefore, we multiply the density of a gas by the weight of 100 cubic inches of air, at the standard temperature and pressure (= 30·00 grains), we immediately find the number required. EXAMPLE: — The density of hydrogen is 0·0692 and 0·0692 × 30 = 2·0760, or the weight of 100 cubic inches of hydrogen, at a temperature of 60° Fahr., and 30 inches of the barometer.

From what has been said, it is evident that no difficulty exists in determining the equivalents of bodies which can be obtained in a gaseous state. Where the equivalent of a fixed body is to be ascertained, or where it is desired to proceed in a different manner, the method employed must depend upon the nature of the substance. We shall consider three of the most simple and general cases, namely, an acid, an alkali, and a neutral body.

1. *Mode of determining the equivalent of an acid.* — For this purpose it is necessary to analyse a salt, the constitution of which is known. If the base or metallic oxide in the salt is one of which the atomic weight is well established, it is very easy to determine the combining proportion of the acid. We say, as the percentage of oxide is to the percentage of acid, so is the atomic weight of the oxide to the atomic weight of the acid. EXAMPLE: — Butyrate of silver has the following composition: —

Oxide of silver	59·487
Butyric acid	40·513
	100·000

We therefore say: —

59·487	:	40·513	::	116	:	79·000	
Percentage of oxide of silver.		Percentage of acid.		Equivalent of oxide of silver.		Equivalent of the acid.	

It must be remembered that the atomic weight so obtained is that of the anhydrous acid, so that one equivalent of water must be added to find the atomic weight of the acid in its ordinary condition. If the equivalent desired be that of a hydrogen acid, the method of proceeding must be slightly modified, but the details need not be given as they are self-evident.

2. *Mode of determining the equivalent of an alkali.* — Several methods present themselves, each possessing certain advantages. Most alkalies, organic and inorganic, form salts well adapted for enabling their atomic weight to be ascertained by analysis. We shall select as an example ammonia, and the salt employed to settle the atomic weight will be the sulphate, which contains: —

Oxide of ammonium	39·40
Sulphuric acid	60·60
	100·00

In the same way that an oxide of known composition is the datum employed to

determine the equivalent of an acid, so, on the other hand, an acid, the formula of which is well established, serves to enable the formula of an alkali to be deduced. We therefore say :—

60·60	:	39·40	::	40·00	:	26·00
Percentage of acid.		Percentage of alkali.		Equivalent of the acid.		Equivalent of the alkali.

Most alkalies, especially those derived from the organic kingdom, form well defined and easily crystallisable compounds with some of the metallic chlorides, especially those of gold, platinum, and palladium. These salts are well adapted for enabling atomic weights to be fixed.

3. *Mode of determining the equivalent of a neutral substance.* — Neutral bodies are formed upon so many models or types that no general method can be given for the required purpose. If volatile at moderate temperatures, the density of the vapour can be ascertained, and this is generally sufficient. Salts have their equivalents found by determining the percentage composition, and proceeding as in examples 1 and 2. The equivalent of a metal is found by forming a compound with some substance, the atomic weight of which is well known, such as oxygen or sulphur. The compound is then carefully analysed. EXAMPLE: — It has been found that 100 parts of oxide of copper contain

Copper	80·00
Oxygen	20·00
	100·00

We therefore say:—

20·00	:	80·00	::	8·00	:	32·00
Percentage of oxygen.		Percentage of copper.		Equivalent of oxygen.		Equivalent of copper.

A precisely analogous mode of proceeding may be adopted with chlorides, iodides, &c.

A careful study of the numbers in the following tables will enable us to observe numerous and highly interesting relations subsisting between them. It has been shown by M. Dumas that certain families or groups of elements fall into natural triads, owing to the relations between their atomic weights. With bodies of this kind, it is found that, if the sums of the atomic weights of the extremes of the series be divided by two, we obtain the atomic weight of the middle body ; thus : —

I.		II.		III.	
Chlorine	35·5	Sulphur	16·00	Lithium	7·00
Iodine	127·0	Tellurium	64·00	Potassium	39·00
	162·5 = 81·25		80·00 = 40·00		46·00 = 23·00
	2		2		2

The triads here are I. chlorine, bromine, and iodine; II. sulphur, selenium, and tellurium; III. lithium, sodium, and potassium. Space will not allow of the subject being developed at greater length in this work. The student, interested in this branch of chemistry, will find much information in the papers of Dr. Odling, recently published in the *Journal of the Chemical Society.*

Table of the Equivalents, &c., of the Non-metallic Elements.

Name.	Symbol.	Equivalent H = 1.	Density as Vapour or Gas.
Bromine	Br	80·00	5·4110
Carbon	C	6·00	0·8290
Chlorine	Cl	35·50	2·4530
Fluorine	Fl	19·00	1·3270
Hydrogen	H	1·00	0·0692
Iodine	I	127·00	8·7827
Nitrogen	N	14·00	0 9713
Oxygen	O	8·00	1·1056
Phosphorus	P	32·00	4·2840
Selenium	Se	40·00	7·6960
Sulphur	S	16·00	2·2140

[NOTE. — The densities of the vapours of carbon, selenium, and fluorine are hypothetical. That of sulphur is usually represented by a number three times as

great as the above, but this is owing to the experiment not having been performed at a sufficiently high temperature.]

Table of the Equivalents of the Metallic Elements.

Name.	Symbol.	Equivalent H = 1	Specific Gravity.
Aluminium	Al	13·67	2·56
Antimony	Sb	129·00	6·70
Arsenic	As	75·00	5·67
Barium	Ba	68·50	4·70
Bismuth	Bi	213·00	9·80
Boron	B	11·00	2·68
Cadmium	Cd	56·00	8·63
Calcium	Ca	20·00	1·58
Cerium	Ce	46·00	
Chromium	Cr	26·27	5·90
Cobalt	Co	29·50	8·53
Copper	Cu	32·00	8·72
Didymium	D	48·00	
Erbium	E		
Glucinum	G	6·97	
Gold	Au	98·33	19·4 to 19·6
Ilmenium	Il		
Iridium	Ir	98·56	18·63
Iron	Fe	28·00	7·84
Lanthanium	La		
Lead	Pb	104·00	11·30
Lithium	L	7·00	0·5936
Magnesium	Mg	12·00	1·75
Manganese	Mn	26·00	8·00
Mercury	Hg	100·00	13·50
Molybdenum	M	48·00	8·60
Nickel	Ni	29·50	8·63
Niobium	Nb		
Osmium	Os	99·41	10·0
Palladium	Pd	53·24	11·50
Platinum	Pt	99·00	21·50
Potassium	K	39·00	0·865
Rhodium	Ro	52·16	11·20
Ruthenium	Ru	52·11	8·60
Silicon	Si	21·00	
Silver	Ag	108·00	10·43
Sodium	Na	23·00	0·97
Strontium	Sr	44·00	2·54
Tantalum	Ta		
Tellurium	Te	64·08	6·30
Terbium	Tb		
Thorium	Th	59·50	
Tin	Sn	59·00	7·29
Titanium	Ti	24·12	5·28
Tungsten	W	92·00	17·2 to 17·6
Uranium	U	60·00	10·15
Vanadium	V	68·46	
Yttrium	Y		
Zinc	Zn	32·52	6·91
Zirconium	Zr	33·58	

It will be seen, from the above table, that a very considerable number of the equivalents are entire multiples of that of hydrogen. M. Dumas and others have, however, shown by elaborate and conclusive experiments, that the doctrine of the equivalents of all elements being multiples of that of hydrogen is not a law of nature, as, in addition to chlorine, there are several undoubted exceptions. — C. G. W.

EREMACAUSIS, — *slow combustion.* This term has been applied to that constant combination of oxygen with carbon and hydrogen, to form carbonic acid and water, which is unceasingly going on in nature, as in the decay of timber, or the "heating"

of hay or grain put together in a moist state. Perfect dryness, and a temperature below freezing, stops this eremacausis, or slow combustion.

ERYTHRIC ACID. Colorific principle of Angola and Madagascar Orchilla weeds (See ORCHILLA.) By macerating the lichen in milk of lime, Stenhouse obtained 12 per cent. of crude erythric acid. It yields red coloured compounds with ammonia. and also in its reaction with hypochlorite of lime. See LICHEN.

ERMINE. See FUR.

ERRATIC BLOCKS. Rounded and weather-worn fragments of the harder rocks, which are found very widely scattered, at great distances from the places from which they are supposed to have been derived. They are generally supposed to have been removed by the transporting power of icebergs and fields of ice.

ESPARTO. A species of rush — the *Stipa tenacissima* — found in the southern provinces of Spain. It is used for making cordage, shoes, matting, baskets, nets, mattresses, sacks, &c. Cables made of esparto are said to be excellent; being light, they float on the surface of the water, and are not therefore so liable as hempen cables to be cut or injured by a foul bottom.—*M'Culloch.*

ESSENCE OF SPRUCE is prepared by boiling the young tops of the *Abies nigra*, or black spruce, in water, and concentrating the decoction by evaporation in a water bath.

ESSENCES. See PERFUMERY.

ESSENTIAL OILS. See OILS, FIXED AND ESSENTIAL, and OTTO.

ESSENCE D'ORIENT, the name of a pearly looking matter procured from the blay or bleak, a fish of the genus *cyprinus*. This substance, which is found principally at the base of the scales, is used in the manufacture of artificial pearls. A large quantity of the scales being scraped into water in a tub, are there rubbed between the hands to separate the shining stuff, which subsides on repose. The first water being decanted, more is added with agitation till the essence is thoroughly washed from all impurities, when the whole is thrown upon a sieve; the substance passes through, but the scales are retained. The water being decanted off, the essence is procured in a viscid state, of a bluish-white colour, and a pearly aspect. The intestines of the same fish are also covered with this beautiful glistening matter. Several other fish yield it, but in smaller proportion. When well prepared, it presents exactly the appearance and reflections of the real pearl, or the finest mother of pearl; properties which are probably owing to the interposition of some portions of this same substance between the laminæ of these shelly concretions. Its chemical nature has not been investigated; it putrefies readily when kept moist, an accident which may however be counteracted by water of ammonia. See PEARLS.

ETCHING VARNISH. (*Aetzgrund-Deckfirniss*, Germ.) Though the practice of this elegant art does not come within the scope of our Dictionary, the preparation of the varnishes, and of the biting menstrua which it employs, legitimately belongs to it.

The varnish of Mr. Lawrence, an English artist resident in Paris, is made as follows: Take of virgin wax and asphaltum, each two ounces, of black pitch and burgundy-pitch, each half an ounce. Melt the wax and pitch in a new earthenware glazed pot, and add to them, by degrees, the asphaltum, finely powdered. Let the whole boil till such time as that, taking a drop upon a plate, it will break when it is cold, on bending it double two or three times betwixt the fingers. The varnish, being then enough boiled, must be taken off the fire, and after it cools a little, must be poured into warm water, that it may work the more easily with the hands, so as to be formed into balls, which must be kneaded, and put into a piece of taffety for use.

Care must be taken, first, that the fire be not too violent, for fear of burning the ingredients, a slight simmering being sufficient; secondly, that whilst the asphaltum is putting in, and even after it is mixed with the ingredients, they should be stirred continually with the spatula; and, thirdly, that the water into which this composition is thrown should be nearly of the same degree of warmth with it, in order to prevent a kind of cracking that happens when the water is too cold.

Preparation of the hard varnish used by Callot, commonly called the Florence Varnish. — Take four ounces of fat oil very clear, and made of good linseed oil, like that used by painters; heat it in a clean pot of glazed earthenware, and afterwards put to it four ounces of mastick well powdered, and stir the mixture briskly till the whole be well melted, then pass the mass through a piece of fine linen into a glass bottle with a long neck, that can be stopped very securely; and keep it for the use that will be explained below.

Method of applying the soft varnish to the plate, and of blackening it. — The plate being well polished and burnished, as also cleansed from all greasiness by chalk or Spanish white, fix a hand-vice on the edge of the plate where no work is intended to be, to serve as a handle for managing it when warm; then put it upon a chafing-dish, in which there is a moderate fire, and cover the whole plate equally with a thin coat of the varnish; and whilst the plate is warm, and the varnish upon it in a fluid state, beat every part of the varnish gently with a small ball or dauber made of cotton

tied up in taffety, which operation smooths and distributes the varnish equall over the plate.

When the plate is thus uniformly and thinly covered with the varnish, it must be blackened by a piece of flambeau, or of a large candle which affords a copious smoke; sometimes two or even four such candles are used together for the sake of despatch, that the varnish may not grow cold, which if it does during the operation, the plate must be heated again, that it may be in a melted state when that operation is performed; but great care must be obtained not to burn it, which when it happens may be easily perceived by the varnish appearing burnt and losing its gloss.

The menstruum used and recommended by Turrell, an eminent London artist, for etching upon steel, was prepared as follows : —

Take Pyroligneous acid 4 parts by measure,
Alcohol 1 part, mix, and add
Nitric acid 1 part.

This mixed liquor is to be applied from 1 to 15 minutes, according to the depth desired. The nitric acid was employed of the strength of 1·28—the double aquafortis of the shops.

The *eau forte* or menstruum for copper, used by Callot, as also by Piranesi, with a slight modification, is prepared, with 8 parts of strong French vinegar,

4 parts of verdigris,
4 ditto sea salt,
4 ditto sal ammoniac,
1 ditto alum,
16 ditto water.

The solid substances are to be well ground, dissolved in the vinegar, and diluted with the water ; the mixture is now to be boiled for a moment, and then set aside to cool. This method is applied to the washed, dried, and varnished plate, after it has suffered the ordinary action of aquafortis, in order to deepen and finish the delicate touches. It is at present called the *eau forte à passer*.

ETHER, C^4H^5O. (Or, for four volumes of vapour, $C^8H^{10}O^2$. *For the nature of four-volume formulæ, see the articles* EQUIVALENTS, CHEMICAL, and FORMULÆ.) *Syn. Sulphuric ether, Oxide of ethyle, Ethylic* or *Vinic ether*, &c. &c. By this term is known the very volatile fluid produced by the action on alcohol of substances having a powerful affinity for water.

Preparation on small scale.— A capacious retort with a moderate sized tubulature is connected with an efficient condensing arrangement. Through the tubulature passes a tube connected with a vessel full of spirit, sp. gr. 0·83. The tube must have a stopcock to regulate the flow. A mixture being made of five parts of alcohol of the density given above, and nine parts of oil of vitriol, it is to be introduced into the retort, and a lamp flame is to be so adjusted as to keep the whole gently boiling. As soon as the ether begins to come over, the stopcock connected with the spirit reservoir is to be turned sufficiently to keep the fluid in the retort at its original level.

Preparation on large scale. — The apparatus is to be arranged on the same principle, but, for fear of fracture, may be constructed of cast iron, lined with sheet lead in the part containing the mixture. The chief disadvantage of this arrangement is its opacity, whereby it becomes impossible to see the contents of the retort, and therefore not so easy to keep the liquid at its original level. In this case the quantity distilling over must be noted and the flow of spirit into the retort regulated accordingly. The most convenient mode of proceeding is to have a large stone bottle with a tubulature at the side near the bottom (like a water filter) to hold the spirit. A tube passes from the bottle to the retort. It has at the end, near the retort or still, a bend downwards leading into the tubulature. If a glass still be used it must for safety be placed in a sand bath. The distillate obtained, either on the large or small scale, is never pure ether, but contains sulphurous and acetic acids, besides water and alcohol. To remove these, the distillate is introduced, along with a little cream of lime, into a large separating globe, such as that mentioned under BROMINE. The whole is to be well agitated, and the lime solution then run off by means of the stopcock. The purified ether still contains alcohol and water, to remove which it should be rectified in a water bath. The fluid will then constitute the ether of commerce. If the second distillation be pushed too far the ether will, if evaporated on the hand, leave an unpleasant after smell, characteristic of impure ether. If wished exceedingly pure, it must be shaken up in the separating globe, with pure water. This will dissolve the alcohol and leave the ether, contaminated only by a little water, which may be removed by digestion with quicklime and redistillation at a very low temperature on a hot water bath.

Pure ether is a colourless mobile liquid, sp. gr. 0·71. It boils at 95° F. The density of its vapour is 2·56 (calculated). Gay-Lussac found it 2·586.

The word ether, like that of alcohol, aldehyde, &c., is now used as a generic term to express a body derived from an alcohol by the elimination of water. Many chemists write the formula C^4H^5O, and call it oxide of ethyl in the same manner as they regard alcohol as the hydrated oxide of the same radical. But there is no just reason for departing from the law we have laid down with reference to the formulæ of organic compounds. (See EQUIVALENTS, CHEMICAL.) We shall therefore write ether $C^8H^{10}O^2$. This view has many advantages. We regard, with Gerhardt and Williamson, ether and alcohol as derived from the type water. Alcohol is two atoms of water in which one equivalent of hydrogen is replaced by ethyle; ether is two atoms of water in which both atoms of hydrogen are replaced by that radical. But there are a large class of compound ethers procurable by a variety of processes. These ethers were long regarded as salts in which oxide of ethyle acted the part of a base. Thus, when butyrate of soda was distilled with alcohol and sulphuric acid, the resulting product was regarded as butyrate of oxide of ethyle. The compound ethers are regarded as two atoms of water in which one equivalent of hydrogen is replaced by the radical of an alcohol, and the other by the radical of an acid. In addition to those there are others more closely resembling the simple ethers. They are founded also on the water type, both atoms of hydrogen being replaced by alcohol radicals, but by different individuals. They are called mixed ethers. The following formulæ show the chemical constitution of all these varieties placed for comparison in juxtaposition with their type: —

$\left.\begin{matrix}H\\H\end{matrix}\right\}O^2$	$\left.\begin{matrix}C^4H^5\\C^4H^5\end{matrix}\right\}O^2$	$\left.\begin{matrix}C^4H^5\\C^2H^3\end{matrix}\right\}O^2$	$\left.\begin{matrix}C^4H^5\\C^8H^7O^3\end{matrix}\right\}O^2$
Water (2 eqs.)	Common ether.	Methylo-ethylic ether.	Butyric ether.

In the above formulæ the first represents the type water. The second common ether, the two equivalents of ethyle replacing the two of hydrogen. In the third, we have a mixed ether, one of the equivalents of hydrogen being replaced by ethyle and the other by methyle. The fourth illustration is that of a compound ether: one of the hydrogens is there replaced by ethyle, and the other by the oxidised radical of butyric acid.

Ether is largely used in medicine and chemistry. In small doses it acts as a powerful stimulant. Inhaled in quantity it is an anæsthetic. It is a most invaluable solvent in organic chemistry for resinous, fatty, and numerous other bodies. — C. G. W.

ETHER, ACETIC, is used to flavour silent corn spirits in making imitation brandy, it requires therefore some additional notice beyond the other ethers. It may be prepared by mixing 20 parts of acetate of lead, 10 parts of alcohol, and 11½ of concentrated sulphuric acid; or 16 of the anhydrous acetate, 5 of the acid, and 4½ of absolute alcohol; distilling the mixture in a glass retort into a very cold receiver, agitating along with weak potash lye the liquor which comes over, decanting the supernatant ether, and rectifying it by re-distillation over magnesia and ground charcoal.

Acetic ether is a colourless liquid of a fragrant smell and pungent taste, of spec. grav. 0·866 at 45° F., boiling at 166° F., burning with a yellowish flame, and disengaging fumes of acetic acid. It is soluble in 8 parts of water.

Acetic ether may be economically made with 3 parts of acetate of potash, 3 of very strong alcohol, and 2 of the strongest sulphuric acid, distilled together. The first product must be re-distilled along with one-fifth of its weight of sulphuric acid; as much ether will be obtained as there was alcohol employed.

ETHIOPS was the name given by the alchemists to certain black metallic preparations. Martial ethiops was the black oxide of iron; mineral ethiops, the black sulphuret of mercury; and ethiops *per se*, the black oxide of mercury.

ETHYLAMINE, C^4H^7N. An exceedingly volatile base, discovered by Wurtz. It is produced in a great number of reactions. Several alkaloids existing in the animal and vegetable kingdoms afford ethylamine on distillation with potash. Its density at 476°, is 0·964. It boils at 66° F. It is regarded as ammonia in which an equivalent of hydrogen is replaced by ethyle. — C. G. W.

ETIOLATION. Deprived of colour by being kept in the dark. Celery, sea-kale, and some other plants are purposely *blanched* or etiolated by excluding the light, this exclusion preventing the formation of *chlorophyll*, the green colouring matter of leaves.

EUCALYPTUS. The gum tree of the New Hollanders. Mr. Backhouse (*Companion to the Botanical Magazine*) says, "We often find large cavities between the annual concentric circles of the trunk filled with a most beautiful red or rich vermilion coloured liquid gum, which flows out as soon as the saw has afforded it an opening. The gum yielded by the *Eucalyptus resinifera* is considered by druggists

as not in the least inferior to the kind which the pterocarpus or red saunders wood of India produces.

EUDIOMETER, is the name of any apparatus subservient to the chemical examination of the atmospheric air. It means a *measure of purity*, but it is employed merely to determine the proportion of oxygen which it may contain. The explosive eudiometer, in which about two measures of hydrogen are introduced into a graduated glass tube, containing five measures of atmospheric air, and an electric spark is passed across the mixture, is the best of all eudiometers; and of these, the siphon form proposed by Dr. Ure in a paper published by the Royal Society of Edinburgh in 1819 is the most convenient.

EUGENIA. A genus of plants of the order Myrtaceæ, called after Prince Eugene of Savoy.

The most remarkable species of this genus is the allspice, or pimento tree. See PIMENTO.

EUKAIRITE. An ore of silver found in a copper mine in Sweden. According to Berzelius it consists of,

Selenium	26·
Silver	38·93
Copper	23·05
Earthy matter	8·90
Carbonic acid, &c.	3·12

EUPIONE. A fluid first discovered by Reichenbach in wood tar. All the properties of eupione agree with the indifferent hydrocarbons found in Boghead naphtha. (See NAPHTHA, BOGHEAD.) Eupione is so indifferent to the action of acids, that it may be repeatedly treated with concentrated oil of vitriol, or fuming nitric acid, without any action taking place. Its density varies with the boiling point, from 0·633 to 0·740. It is said to be contained among the products of the distillation of rape oil. There is no doubt that these hydrocarbons will, eventually, be of great value in the arts.—C. G. W.

EURITE. A granulous compound of feldspar and quartz, with sometimes garnet. "It generally occurs as veins, or as local masses in other granites, and rarely, I believe, as veins traversing other rocks at a distance from granite. These, therefore are probably veins of segregation, or of injection during consolidation, and not of subsequent formation."—*Jukes's Student's Manual of Geology.*

EVAPORATION (Eng. and Fr.; *Abdampfen; Abdunsten*, Germ.) is the process by which any substance is converted into, and carried off, in vapour. Though ice, camphor, and many other solids evaporate readily in dry air, we shall consider, at present, merely the vaporisation of water by heat artificially applied.

The vapour of water is an elastic fluid, whose tension and density depend upon the temperature of the water with which it is in contact. Thus the vapour rising from water heated to 165° F. possesses an elastic force capable of supporting a column of mercury 10·8 high; and its density is such that 80 cubic feet of such vapour contain one pound weight of water; whereas 52½ cubic feet of steam of the density corresponding to a temperature of 212° and a pressure of 30 inches of mercury, weigh one pound. When the temperature of the water is given, the elasticity and specific gravity of the vapour emitted by it, may be found.

Since the vapour rises from the water only in virtue of the elasticity due to its gaseous nature, it is obvious that no more can be produced, unless what is already incumbent upon the liquid have its tension abated, or be withdrawn by some means. Suppose the temperature of the water to be midway between freezing and boiling, viz. 122° Fahr., as also that of the air in contact with it to be the same, but replete with moisture, so that its interstitial spaces are filled with vapour of corresponding elasticity and specific gravity with that given off by the water, it is certain that no fresh formation of vapour can take place in these circumstances. But the moment a portion of vapour is allowed to escape, or is drawn off by condensation to another vessel, an equivalent portion of vapour will be immediately exhaled from the water.

The pressure of the air and of other vapours upon the surface of water in an open vessel, does not prevent evaporation of the liquid; it merely retards its progress. Experience shows that the space filled with an elastic fluid, as air or other gaseous body, is capable of receiving as much aqueous vapour as if it were vacuous, only the repletion of that space with the vapour proceeds more slowly in the former predicament than in the latter, but in both cases it arrives eventually at the same pitch. Dr. Dalton very ingeniously proved, that the particles of aeriform bodies present no permanent obstacle to the introduction of a gaseous atmosphere of another kind among them, but merely obstruct its diffusion momentarily, as if by a species of friction. Hence, exhalation at atmospheric temperatures is promoted by the mechanical diffusion of the vapours

through the air with ventilating fans or chimney draughts; though under brisk ebullition, the force of the steam readily overcomes that mechanical obstruction.

The quantities of water evaporated under different temperatures in like times, are proportional to the elasticities of the steam corresponding to these temperatures. A vessel of boiling water exposing a square foot of surface to the fire, evaporates about 725 grains in the minute; the elasticity of the vapour is equivalent to 30 inches of mercury. To find the quantity that would be evaporated from the same surface per minute at a heat of 88° F.:—At this temperature the steam incumbent upon water is capable of supporting 1·28 inch of mercury; whence the rule of proportion is 30 : 1·28 :: 725 : 30·93; showing that about 31 grains of water would be evaporated in the minute. If the air contains already some aqueous vapour, as it commonly does, then the quantity of evaporation will be proportional to the difference between the elastic force of that vapour, and what rises from the water.

Suppose the air to be in the hygrometric state denoted by 0·38 of an inch of mercury, then the above formula will become 30 : 1·28 — 0·38 :: 725 : 21·41; showing that not more than 21½ grains would be evaporated per minute under these circumstances.

The elastic tension of the atmospheric vapour is readily ascertained by the old experiment of Le Roi, which consists in filling a glass cylinder (a narrow tumbler for example) with cold spring water, and noting its temperature at the instant it becomes so warm that dew ceases to be deposited upon it. This temperature is that which corresponds to the elastic tension of the atmospheric vapour. See VAPOUR, Table of.

Whenever the elasticity of the vapour, corresponding to the temperature of the water, is greater than the atmospheric pressure, the evaporation will take place not only from its surface, but from every point in its interior; the liquid particles throughout the mass assuming the gaseous form, as rapidly as they are actuated by the caloric, which subverts the hydrostatic equilibrium among them, to constitute the phenomena of ebullition. This turbulent vaporisation takes place at any temperature, even down to the freezing point, provided the pneumatic pressure be removed from the liquid by the air pump, or any other means. Ebullition always accelerates evaporation, as it serves to carry off the aqueous particles not simply from the surface, but from the whole body of the water.

The vapours exhaled from a liquid at any temperature contain more heat than the fluid from which they spring; and they cease to form whenever the supply of heat into the liquid is stopped. Any volume of water requires for its conversion into vapour about *five times* as much heat as is sufficient to heat it from the freezing to the boiling temperature. The heat, in the former case, seems to be absorbed, being inappreciable by the thermometer; for steam is no hotter than the boiling water from which it rises. It has been therefore called by Dr. Black, *latent heat*; in contradistinction to that perceived by the touch and measured by the thermometer, which is called *sensible heat*. The quantity of heat absorbed by one volume of water in its conversion into steam, is about 1000° Fahr.; it would be adequate to heat 1000 volumes of water, one degree of the same scale. Were the vessel charged with water so heated, opened, it would be instantaneously emptied by vaporisation, since the whole caloric, equivalent to its constitution as steam, is present. When upon the other hand, steam is condensed by contact with cold substances, so much heat is set free as is capable of heating about five times its weight of water from 32° to 212° F.

Equal weights of vapour of any temperature contain equal quantities of heat; for example, the vapour exhaled from one pound of water, at 77° F., absorbs during its formation, and will give out in its condensation, as much heat as the steam produced by one pound of water at 212° F. The first portion of vapour with a tension = 30 inches, occupies a space of 27·31 cubic feet; the second, with a tension of 0·92 inch, occupies a space of 890 cubic feet.* Suppose that these 890 volumes were to be compressed into 27·31 in a cylinder capable of confining the heat, the temperature of the vapour would rise from 77° to 212°, in virtue of the condensation, as air becomes so hot by compression in a syringe, as to ignite *amadou*. The latent heat of steam at 212° F. is 1180° — 180 = 1000; that of vapour, at 77°, is 1183 — 45 = 1135; so that, in fact, the lower the temperature at which the vapour is exhaled, the greater is its latent heat, as Joseph Black and James Watt long ago proved by experiments upon distillation and the steam engine.

From the preceding researches it follows, that evaporation may be effected upon two different plans: —

1. Under the ordinary pressure of the atmosphere; and that either,

* One pound avoirdupois of water contains 27·72 cubic inches; one cubic inch of water forms 1696 cubic inches of steam at 212° F.: therefore one pound of water will form 27·31 cubic feet of such steam; and 0·93 : 30 :: 27·31 : 890 cubic feet.

A, by external application of heat to boilers, with *a*, an open fire; *b*, steam; *c*, hot liquid *media*.

B, by evaporation with air; *a*, at the ordinary temperature of the atmosphere; *b*, by currents of warm air.

2. Under progressively lower degrees of pressure than the atmospheric, down to evaporation in as perfect a vacuum as can be made.

It is generally affirmed, that a thick metallic boiler obstructs the passage of the heat through it so much more than a thin one, as to make a considerable difference in their relative powers of evaporating liquids. Dr. Ure states that he made a series of experiments upon this subject. Two cylindrical copper pans, of equal dimensions, were provided; but the metal of the one was twelve times thicker than that of the other. Each being charged with an equal volume of water, and placed either upon the same hot plate of iron, or immersed, to a certain depth, in a hot solution of muriate of lime, he found that the ebullition was greatly more vigorous in the thick than in the thin vessel, which he ascribed to the conducting substance up the sides, above the contact of the source of heat, being 12 times greater in the former case than in the latter.

If the bottom of a pan, and the portions of the sides, immersed in a hot fluid medium, solution of caustic potash or muriate of lime, for example, be corrugated, so as to contain a double expanse of metallic surface, that pan will evaporate exactly double the quantity of water, in a given time, which a like pan, with smooth bottom and sides, will do immersed equally deep in the same bath. If the corrugations contain three times the quantity of metallic surface, the evaporation will be threefold in the above circumstances. But if the pan, with the same corrugated bottom and sides, be set over a fire, or in an oblong flue, so that the current of flame may sweep along the corrugations, it will evaporate no more water from its interior than a smooth pan of like shape and dimensions placed alongside in the same flue, or over the same fire. This curious fact Dr. Ure states he has verified upon models constructed with many modifications. Among others, he caused a cylindrical pan, 10 inches diameter, and 6 inches deep, to be made of tin-plate, with a vertical plate soldered across its diameter; dividing it into two equal semi-cylindrical compartments. One of these was smooth at the bottom, the other corrugated; the former afforded as rapid an evaporation over the naked fire as the latter, but it was far outstripped by its neighbour when plunged into the heated liquid medium.

If a shallow pan of extensive surface be heated by a subjacent fire, by a liquid medium, or a series of steam pipes upon its bottom; it will give off less vapour in the same time when it is left open, than when partially covered. In the former case, the cool incumbent air precipitates by condensation a portion of the steam, and also opposes considerable mechanical resistance to the diffusion of the vaporous particles. In the latter case, as the steam issues with concentrated force and velocity from the contracted orifice, the air must offer less proportional resistance, upon the known hydrostatic principle of the pressure being as the areas of the respective bases of the communicating vessels.

In evaporating by surfaces heated with ordinary steam, it must be borne in mind that a surface of 10 square feet will evaporate fully one pound of water per minute, or $725 \times 10 = 7250$ gr., the same as over a naked fire; consequently the condensing surface must be equally extensive. Suppose that the vessel is to receive of water 2500 lbs., which corresponds to a boiler 5 feet long, 4 broad, and 2 deep, being 40 cubic feet by measure, and let there be laid over the bottom of this vessel 8 connected tubes, each 4 inches in diameter and 5 feet long, possessing therefore a surface of 4·8 feet square. If charged with steam, they will cause the evaporation of half a pound of water per minute. The boiler to supply the steam for this purpose must expose a surface of 4·8 square feet to the fire. It has been proved experimentally that 10 square feet surface of thin copper can condense 3 lbs. of steam per minute, with a difference of temperature of 90 degrees Fahr. In the above example, 10 square feet evaporate 1 lb. of water per minute; the temperature of the evaporating fluid being 212° F., consequently $3 : 1 :: 90 : \frac{90}{3}$. During this evaporation the difference of the temperature is therefore = 30°. Consequently the heat of the steam placed in connection with the interior of the boiler, to produce the calculated evaporation, should be, $212 + 30 =$ 242°, corresponding to an elastic force of 53·6 inches of mercury. Were the temperature of the steam only 224, the same boiler in the same time would produce a diminished quantity of steam, in the proportion of 12 to 30; or to produce the same quantity the boiler or tubular surface should be enlarged in the proportion of 30 to 12. In general, however, steam boilers employed for this mode of evaporation are of such capacity as to give an unfailing supply of steam.

We shall now illustrate by some peculiar forms of apparatus, different systems of evaporation. *Fig.* 729 explains the principles of evaporating in vacuo. A B repre-

sents a pan or kettle charged with the liquor to be evaporated. The somewhat wide orifice c, secured with a screw-plug, serves to admit the hand for the purpose of

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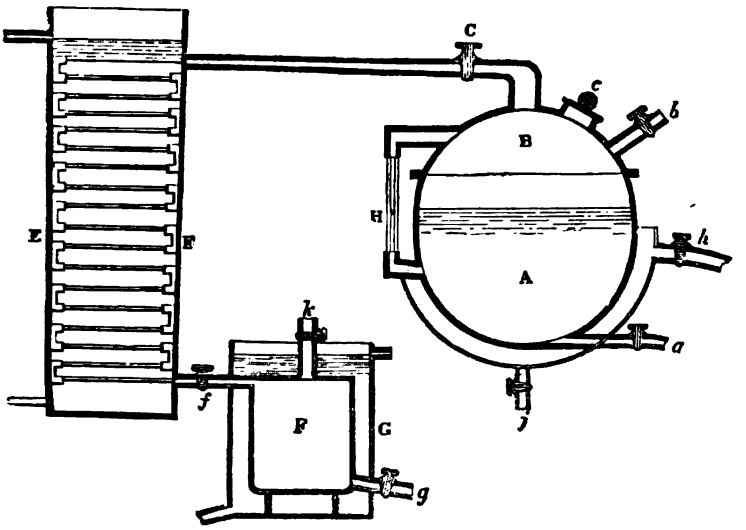


cleaning it thoroughly out when the operation is finished; *h* is the pipe of communication with the steam boiler; *b* is a tube prolonged and then bent down with its end plunged into the liquor to be evaporated, contained in the charging back (not shown in the figure). H is a glass tube communicating with the vacuum pan at the top and bottom, to show by the height of the column the quantity of liquid within. The eduction evaporating pipe c is provided with a stop-cock to cut off the communication when required. *i* is a tube for the discharge of the air and the water from the steam-case or jacket; the refrigerator E is best formed of thin copper tubes about 1 inch in diameter, arranged zig-zag or spirally like the worm of a still in a cylinder. The small air-tight condenser F, connected with the efflux pipe *f* of the refrigerator, is furnished below with a discharge cock *g*, and surrounded by a cooling case, for the collection of the water condensed by the refrigerator. In its upper part there is a tube *k*, also furnished with a cock, which communicates with the steam boiler, and through which the pan A B is heated.

The operation of this apparatus is as follows: after opening the cocks c, *f*, *g*, and before admitting the cold water into the condenser E, the cock of the pipe *k* is opened, in order that by injecting steam it may expel the included air; after which the cocks *k* and *g* are to be shut. The water must now be introduced into the condenser, and the cock *b* opened, whereon the liquid to be evaporated rises from the charging back, through the tube *b*, and replenishes the vacuum pan to the proper height, as shown by the register glass tube H. Whenever the desired evaporation or concentration is effected, the cock c must be closed, the pipe *k* opened, so as to fill the pan with steam, and then the efflux cock *a* is opened to discharge the residuary liquor. By shutting the cocks *a* and *k*, and opening the cock *b*, the pan will charge itself afresh with liquor, and the operation will be begun anew, after *b* has been shut and c opened.

The contents of the close water cistern F, may be drawn off during each operation. For this purpose, the cock *f* must first be shut, the cold water is to be then run out of the condenser G, and *k* and *g* are to be opened. The steam entering by *k* makes the water flow, but whenever the steam itself issues from the cock *g*, this orifice must be immediately shut, the cock *f* opened, and the cold water again introduced, whereupon the condensed water that had meanwhile collected in the under part of the refrigerator, flows off into the condenser vessel F. Since some air always enters with the liquor sucked into the pan, it must be removed at the time of drawing off the water from the two condensers, by driving steam through the apparatus. This necessity will be less urgent if the liquor be made to boil before being introduced into the vacuum pan.

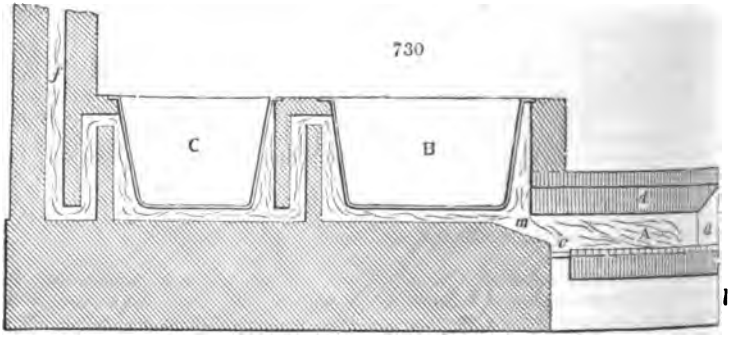
Such an apparatus may be modified in size and arrangement to suit the peculiar

object in view, when it will be perfectly adapted for the concentration of extracts of every kind, as well as saline solutions containing vegetable acids or alkalies. The interior vessel A B should be made of tinned or plated copper. For an account of Howard's vacuum pan, made upon the same principle, see SUGAR.

When a boiler is set over a fire, its bottom should not be placed too near the grate, lest it refrigerate the flame, and prevent that vivid combustion of the fuel essential to the maximum production of heat by its means. The evil influence of leaving too little room between the grate and the copper may be illustrated by a very simple experiment. If a small copper or porcelain capsule containing water be held over the flame of a candle a little way above its apex, the flame will suffer no abatement of brightness or size, but will continue to keep the water briskly boiling. If the capsule be now lowered into the middle of the flame, this will immediately lose its brightness, becoming dull and smoky covering the bottom of the capsule with soot; and, owing to the imperfect combustion, though the water is now surrounded by the flame, its ebullition will cease.

Fig. 730 is a section of two evaporating coppers *en suite*, so mounted as to favour the full combustion of the fuel. A is the hearth, in which wood or coal may be

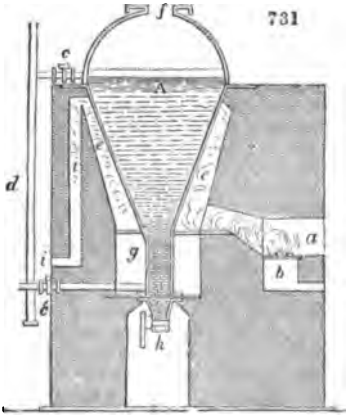
730



burned. For coal, the grate should be set higher and be somewhat smaller. *a* is the door for feeding the fire; *d*, an arch of fire-bricks over the hearth; *c*, a grate through which the ashes fall into the pit beneath, capable of being closed in front to any extent by a sliding door *b*. B and C are two coppers encased in brickwork; *f* the flue. At the end of the hearth near *m*, where the fire plays first upon the copper, the sole is made somewhat lower and wider, to promote the spreading of the flame under the vessel. The second copper C, receives the benefit of the waste heat; it may be placed upon a higher level, so as to discharge its concentrated liquor by a stop-cock or siphon into the first.

Fig. 731 represents a pan for evaporating liquids, which are apt, during concentration, to let fall crystals or other sediment.

731



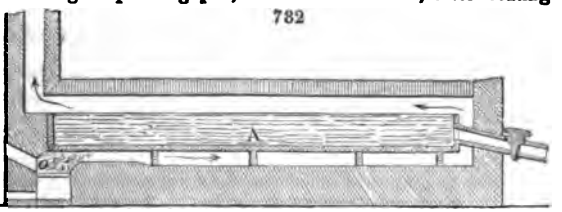
These would be injured either by the fire playing upon the bottom of the pan, or, by adhesion to it, they would allow the metal to get red hot, and in that state run every risk of being burnt or rent on the sudden intrusion of a little liquor through the incrustation. When large coppers have their bottoms planted in loam, so that the flame circulates in flues round their sides, they are said to be *cold-set*.

A is a pear-shaped pan, charged with the liquid to be evaporated; it is furnished with a dome cover, in which there is an opening with a flange *f*, for attaching a tube, to conduct the steam wherever it may be required. *a* is the fire-place; *b*, the ash-pit. The conical part terminates below in the tube *g*, furnished with a stop-cock at its nozzle *h*. Through the tube *c d c'*, furnished above and below with the stop-cocks *c* and *c'*, the liquid is run from the charging back or reservoir. During the operation, the upper cock *c* is kept partially open, to replace the fluid as

it evaporates; but the under cock *c'* is shut. The flame from the fire-place plays round the kettle in the space *e*, and the smoke escapes downwards through the flue *i* into the chimney. The lower cylindrical part *g* remains thus comparatively cool, and collects the crystalline or other solid matter. After some time, the under stop-cock *c'*, upon the supply-pipe, is to be opened to admit some of the cold liquor into the cylindrical neck. That cock being again shut, the sediment settled, and the large stop-cock (a horizontal side valve would be preferable) *h* opened, the crystals are suffered to descend into the subjacent receiver; after which the stop-cock *h* is shut and the operation is continued. A construction upon this principle is well adapted for heating dyeing coppers, in which the sediment should not be disturbed, or exposed to the action of the fire. The fire-place should be built as for the brewing copper.

Fig. 732 represents an oblong evaporating pan, in which the flame, after beating along its bottom, turns up at its further end, plays back along its surface, and passes off into the chimney. A is a rectangular vessel, from 10 to 15 feet long, 4 to 6 feet broad, and 1 or 1½ feet deep. The fire-bricks, upon which the pan rests, are so arranged as to distribute the flame equally along its bottom.

732



Leidenfrost in 1756 (*Annales de Chimie*) observed some remarkable facts connected with evaporation, which have since received some striking illustration from the experiments of M. Boutigny.

When water is thrown on a plate heated considerably above the boiling point of water, the liquid assumes a spheroidal form, and this condition has hence received the name of the "spheroidal state." This water rolls about like melted crystal without any signs of ebullition, and it is dissipated but very slowly. The explanation usually given is as follows:—"The cause of the phenomena appears to be this, water exhibits an attraction for the surface of almost all solids, and wets them; fluid mercury exhibits the opposite property, or repulsion for most surfaces. The attraction of water for surfaces brings it into the closest contact with them, and greatly promotes the communication of heat by a heated vessel to the water contained in it. But heat appears to develope a repulsive power in bodies, and it is probable that, above a peculiar temperature, the heated metal no longer possesses this attraction for water. The water not being attracted to the surface of the hot metal, and induced to spread over it, is not rapidly heated, and therefore boils off slowly."—*Graham.*

The explanation given by this excellent authority on all matters connected with physico-chemical science has been selected as representing fairly the prevailing view. It is not, however, quite satisfactory. The water is said to be at a sensible distance from the hot plate, and a layer of aqueous vapour of very high temperature is known to surround the water, and yet the spheroidal water does not acquire the boiling temperature. Here is evidence of some peculiar, and as yet unexplained condition, belonging, either to heat of a certain kind or degree, or to the molecules of the body under its influence.

Boutigny observed that water may pass into the spheroidal state at any temperature above 340° F., and remain in that state until the temperature falls to 288° F., when evaporation rapidly ensues. Ether and alcohol pass into the spheroidal state at 142° F. and 273° F. A thermometer being plunged in liquids while in the spheroidal state, indicated the following temperatures:—

Water	205·7° F.
Absolute alcohol	167·9
Ether	93·6
Hydrochloric ether	50·9
Sulphurous acid	13·1

All these being some degrees below the boiling temperature of those fluids.

Boutigny has shown that the vapour escaping from water in the spheroidal state, although it has a very elevated temperature, does not possess the usual elasticity of steam; it does not exert an expansive power. But if the vessel from which the vapour is forming is allowed to cool, to a certain point, a degree of elasticity equal to the elevated temperature of the vapour is suddenly exerted. This is supposed by Boutigny to explain many steam boiler explosions.

Whenever evaporation takes place, it should be remembered, it produces cold — that is, it lowers the temperature of the body from which the evaporation is taking

place. Leslie, by the evaporation of ether in vacuo, froze mercury. Thilorier solidified carbonic acid by the intense cold produced by its own evaporation. Boutigny froze water in a red hot vessel, by the evaporation of sulphurous acid from the heated vessel in which the water is in the spheroidal state.

Further remarks on these points will be found under the heads respectively of COAL, STEAM BOILERS, VAPOUR.

EXOSMOSE and ENDOSMOSE. As some manufacturing processes involve the phenomena expressed by these two words, it appears necessary briefly to explain them.

When two liquids are separated by a porous sheet of animal membrane, unglazed earthenware, porous stone, or clay, these liquids gradually diffuse themselves; and supposing salt and water to be on one side of the division, and water only on the other, the saline solution passes in one direction, while the water, though with less intensity, passes in another.

Instead of the two words introduced by Dutrochet, Professor Graham proposes the use of the single term Osmose (from ὄσμος, impulsion).

It was supposed that there was, at the same time, an impulsive force acting from without and another acting from within; that there was indeed a current *flowing in*, and another *flowing out*. It however appears to be proved that the *osmose* between water and saline solutions, consists not in the passage of two liquid currents, but in the passage of particles of the salt in one direction, and of pure water in the other. Professor Graham has observed, that common salt diffuses into water, through a thin membrane of ox-bladder deprived of its outer muscular coating, at the same rate as when no membrane is interposed. This force plays an important part in the functions of life, and it will be found to explain many of the phenomena associated with Dyeing, Tanning, &c.

EXOGENOUS. A botanical term, signifying growing by addition to the outer parts of the stem.

The stem varies in structure in four principal ways. It is either formed by successive additions to the outside of the wood, when it is called *exogenous*, or by successive additions to its centre, when it is called *endogenous*, or by the union of the bases of leaves, and the extension of the point of the axis, which is called *acrogenous*, or by simple elongation or dilatation where no leaves or buds exist, as among *Thallogens*. — *Lindley*.

EXPANSION (Eng. and Fr.; *Ausdehnung*, Germ.) is the increase of bulk experienced by all bodies when heated, unless a change in molecular arrangement takes place, as in the case of clays in the potter's kiln.

Table I. exhibits the linear expansion of several solids by an increase of temperature from 32° to 212° Fahr.; Table II. exhibits the expansion in bulk of certain liquids.

TABLE I. — *Linear Dilatation of Solids by Heat.*

Dimensions which a bar takes at 212° whose length at 32° is 1·000000.

Substances.	Authority.	Dilatation in Decimals.	Dilatation in Vulgar Fractions.
Glass tube	Smeaton	1·00083333	
do.	Roy	1·00077615	
do.	Deluc's mean	1·00082800	1/1218
do.	Dulong and Petit	1·00086130	1/1161
do.	Lavoisier and Laplace	1·00081166	1/1232
Plate glass	do. do.	1·000890890	1/1123
do. crown glass	do. do.	1·00087572	1/1142
do. do.	do. do.	1·00089760	1/1116
do. do.	do. do.	1·00091751	
do. rod	Roy	1·00080787	
Deal	Roy, as glass	—	
Platina	Borda	1·00085655	1/1171
do.	Dulong and Petit	1·00088420	
do.	Troughton	1·00099180	
do. and glass	Berthoud	1·00110000	
Palladium	Wollaston	1·00100000	
Antimony	Smeaton	1·00108300	
Cast-iron prism	Roy	1·00110940	
Cast-iron	Lavoisier, by Dr. Young	1·00111111	
Steel	Troughton	1·00118990	
Steel rod	Roy	1·00114470	
Blistered steel	Phil. Trans. 1795, 428	1·00112500	
do.	Smeaton	1·00115000	

Substances.	Authority.	Dilatation in Decimals.	Dilatation in Vulgar Fractions.
Steel not tempered	Lavoisier and Laplace	1·00107875	1/927
do. do.	do. do.	1·00107956	1/926
do. tempered yellow	do. do.	1·00136900	
do. do. do.	do. do.	1·00138600	
do. do. do. at a higher heat	do. do.	1·00123956	1/807
Steel	Troughton	1·00118980	
Hard steel	Smeaton	1·00122500	
Annealed steel	Muschenbroek	1·00122000	
Tempered steel	do.	1·00137000	
Iron	Borda	1·00115600	
do.	Smeaton	1·00125800	
Soft iron, forged	Lavoisier and Laplace	1·00122045	
Round iron, wire drawn	do. do.	1·00123504	
Iron wire	Troughton	1·00144010	
Iron	Dulong and Petit	1·00118203	1/845
Bismuth	Smeaton	1·00139200	
Annealed gold	Muschenbroek	1·00146000	
Gold	Ellicot, by comparison	1·00150000	
do. procured by parting	Lavoisier and Laplace	1·00146606	1/683
do. Paris standard, unannealed	do. do.	1·00155155	1/645
do. do. annealed	do. do.	1·00151361	1/661
Copper	Muschenbroek	1·0019100	
do.	Lavoisier and Laplace	1·00172244	1/581
do.	do. do.	1·00171222	1/584
do.	Troughton	1·00191880	
do.	Dulong and Petit	1·00171821	1/583
Brass	Borda	1·00178300	
do.	Lavoisier and Laplace	1·00186671	
do.	do. do.	1·00188971	
Brass scale, supposed from Hamburg	Roy	1·00185540	
Cast brass	Smeaton	1·00187500	
English plate-brass, in rod	Roy	1·00189280	
do. do. in a trough form	do.	1·00189490	
Brass	Troughton	1·00191880	
Brass wire	Smeaton	1·00193000	
Brass	Muschenbroek	1·00216000	
Copper 8, tin 1	Smeaton	1·00181700	
Silver	Herbert	1·00189000	
do.	Ellicot, by comparison	1·0021000	
do.	Muschenbroek	1·00212000	
do. of cupel	Lavoisier and Laplace	1·00190974	1/524
do. Paris standard	do. do.	1·00190868	1/524
Silver	Troughton	1·0020826	
Brass 16, tin 1	Smeaton	1·00190800	
Speculum metal	do.	1·00193300	
Spelter solder; brass 2, zinc 1	do.	1·00205800	
Malacca tin	Lavoisier and Laplace	1·00193765	1/518
Tin from Falmouth	do. do.	1·00217298	1/452
Fine pewter	Smeaton	1·00228300	
Grain tin	do.	1·00248300	
Tin	Muschenbroek	1·00284000	
Soft solder; lead 2, tin 1	Smeaton	1·00250800	
Zinc 8, tin 1, a little hammered	do.	1·00269200	
Lead	Lavoisier and Laplace	1·00284836	1/351
do.	Smeaton	1·00286700	
Zinc	do.	1·00294200	
Zinc, hammered out ¼ inch per foot	do.	1·00301100	
Glass, from 32° to 212°	Dulong and Petit	1·00086130	1/1161
do. from 212° to 392°	do. do.	1·00091827	1/1089
do. from 392° to 572°	do. do.	1·00101114	1/987

The last two measurements by an air thermometer.

TABLE II. — *Expansion of certain Liquids by being heated from* 32° *to* 212°.

Substances.	Authority.	Expansion in Decimals.	Expansion in Vulgar Fractions.
Mercury - - - - -	Dulong and Petit. -	0·01801800	$\frac{1}{55\cdot5}$
do. in glass - - -	do. do. -	0·01543200	$\frac{1}{65}$
Water from its maximum density	Kirwan - - -	0·04332	$\frac{1}{23}$
Muriatic acid (sp. gr. 1·137) -	Dalton - - -	0·0600	$\frac{1}{17}$
Nitric acid (sp. gr. 1·40) - -	do. - - -	0·1100	$\frac{1}{9}$
Sulphuric acid (sp. gr. 1·85) -	do. - - -	0·0600	$\frac{1}{17}$
Alcohol (to its boiling point)? -	do. - - -	0·1100	$\frac{1}{9}$
Water - - - - -	do. - - -	0 0460	$\frac{1}{22}$
Water, saturated with common salt	do. - - -	0·0500	$\frac{1}{20}$
Sulphuric ether (to its boiling point)?	do. - - -	0·0700	$\frac{1}{14}$
Fixed oils - - - - -	do. - - -	0·0800	$\frac{1}{12\cdot5}$
Oil of turpentine - - - -	do. - - -	0 0700	$\frac{1}{14}$

If the density of water at 39° be called 1·00000,
at 212° it becomes - - - - 0·9548,
and its volume has increased to - - 1·04734;
at 77° it becomes - - - - - 0·9973587,
and its volume has increased to only - 1·00265,
which, though one fourth of the whole range of temperature, is only $\frac{1}{19}$ of the total expansion. Water at 60° F. has a specific gravity of - 0·9991253,
and has increased in volume from 39° to 1·00008,
which is only about $\frac{1}{30}$ of the total expansion to 212°, with $6\frac{1}{2}$ of the total range of temperature.

All gases expand the same quantity by the same increase of temperature, which from 32° to 212° Fahr. = $\frac{180°}{480°} = \frac{3}{8}$, or 100 volumes become 1·375. For each degree of Fahr. the expansion is $\frac{1}{480}$.

When dry air is saturated with moisture, its bulk increases, and its specific gravity diminishes, because aqueous vapour is less dense than air, at like temperatures.

The following Table gives the multipliers to be employed for converting one volume of moist gas at the several temperatures, into a volume of dry gas.

Temperature.	Multiplier.	Temperature.	Multiplier.
53° F.	0·9870	64°	0·9799
54	0 9864	65	0·9793
55	0·9858	66	0·9786
56	0·9852	67	0·9779
57	0·9846	68	0·9772
58	0·9839	69	0·9765
59	0·9833	70	0·9758
60	0·9827	71	0·9751
61	0·9920	72	0·9743
62	0·9813	73	0·9735
63	0·9806		

Lavoisier and Laplace arrived, after an extensive series of experiments, at the two important conclusions following: —

1st. All solid bodies whatever, being gradually heated from the temperature of melting ice to that of boiling water, and then gradually cooled from the temperature of boiling water to that of melting ice, will be found to have exactly the same dimensions at the same temperature during the process of heating and cooling; the gradual diminution of bulk in cooling corresponding exactly with the gradual increase of bulk in heating.

2nd. Glass and metallic bodies gradually heated from the temperature of melting ice to that of boiling water, undergo degrees of expansion proportional to those of mercury at the same temperature; that is to say, between the limits just mentioned, the expansion of the solid corresponding to two degrees of the thermometer, is twice the expansion which corresponds to one degree, the expansion which corresponds to

three degrees is three times the expansion which corresponds to one degree, and so on; the quantity of expansion being multiplied in the same proportion as the number of degrees through which the thermometer has risen is multiplied. See HEAT, *Lardner's Cyclopedia.*

Experiments by Fresnel, Forbes, Powell, Trevelyan, and Tyndal have a tendency to prove that heat occasions a repulsion between the particles of matter at small distances. If a heated poker is laid slantingly on a block of lead at the ordinary temperature, it will commence to vibrate, first slowly, and will increase with such rapidity as to produce a musical note, which continues for some time, usually changing to an octave at the termination. These results would appear to prove a movement amongst the particles constituting the bar.

Some remarkable examples of expansion are furnished by the influence of sunshine on the Britannia Tubular Bridge.

The most interesting effect is that produced by the sun shining on one side of the tube, or on the top, while the opposite side and bottom remain shaded and comparatively cool; the heated portions of the tube expand, and thereby warp or bend the tube towards the heated side, the motion being sometimes as much as 2½ inches vertically and 2½ inches laterally.

While the tubes were supported on the temporary piers on the beach, these motions were easily observed. An arm carrying a pencil was fixed on the south side of the tube, at the centre, and a board was fixed on a post independent of the tube, and at right angles to it; the pencil was pressed against the board by a spring, and the rise and fall, and the lateral motions of the tube, were consequently placed on the board. In this way a very interesting diagram was taken daily. The lowest part of each figure is the starting point, or normal position of the tube, to which the pencil always accurately returns during the night. As soon as the sun rises in the morning it starts towards the right hand, rising obliquely, the top and one side of the tube being warmed, and the bottom and opposite side remaining unaffected. It continues thus till one o'clock, when the sun, having ceased to shine on the southern side, begins to warm the northern side, the top still retaining its high temperature, the tube thus acquires a nearly horizontal motion towards the left hand, the slight descent in the line indicating the diminished effects of the sun on the top as it gradually sinks. The greatest deflection to the left hand is not attained until sunset, after which the tube rapidly descends in a uniformly curved line to its resting point. In the summer time this point is hardly attained before the rising sun compels it to commence its journey anew. When the sun is frequently obscured by passing clouds, very curious diagrams are obtained. During the absence of the sun the tube begins to cool rapidly, and to return to its normal position, every passing cloud is thus beautifully recorded.

The middle of the centre arch of Southwark Iron Bridge rises one inch in the height of summer. When great lengths of iron pipe are laid down for the conveyance of steam or hot water, sliding joints are necessary to prevent destruction either of the apparatus or of the building in which it is placed.

The practical applications made of the expansion and contraction of metals by heat are many. The tire of a wheel is put on hot, and by its contraction on cooling, firmly binds the other parts of the wheel together; boiler plates are riveted with red-hot rivets; collars of metal are driven on while hot, and the like.

Mollard drew together the walls of a building that had bulged, by screwing up bars of iron tight to the walls while they were hot, and a similar process was adopted in the Cathedral of Armagh.

Playfair and Joule (*Chemical Society's Memoirs*) have made a valuable series of researches on the expansion of bodies by heat, principally salts; these have not however any sufficient practical bearing to occupy our space.

EXPRESSED OILS. See OILS.

EXTRACTS. (*Extraits*, Fr; *Extracten*, Germ.) The older apothecaries used this term to designate the product of the evaporation of any vegetable juice or infusion, or decoction; whether the latter two were made with water, alcohol, or ether; whence arose the distinction of aqueous, alcoholic, and etherous extracts.

Fourcroy made many researches upon these preparations, and supposed that they had all a common basis, which he called the *extractive* principle. But Chevreul and other chemists have since proved that this pretended principle is a heterogeneous and very variable compound. By the term *extract* therefore is now meant merely the whole of the soluble matters obtained from vegetables, reduced by careful evaporation to either a pasty or solid consistence. The watery extracts, which are those most commonly made, are as various as the vegetables which yield them; some containing chiefly sugar or gum in great abundance, and are therefore innocent or inert; while others contain very energetic impregnations. The conduct of the evaporating heat is the capital point in the preparation of extracts. They should be always prepared if

possible, from the juice of the fresh plant, by subjecting its leaves or other succulent part, to the action of a powerful screw, or hydraulic press; and the evaporation should be effected by the warmth of a water bath, heated not beyond 100° or 120 F. Steam heat is now applied advantageously in some cases, where it is not likely to decompose any of the principles of the plant. But by far the best process for making extracts is in vacuo, upon the principles explained in the article EVAPORATION. It is much easier to fit up a proper apparatus of this kind, than most practical men imagine. The vacuum may either be made through the agency of steam, as there pointed out, or by means of an air-pump. One powerful air-pump may form and maintain a good vacuum under several receivers, placed upon the flat ground flanges of so many basins, each provided with a stop-cock at its side for exhaustion. The air-less basin containing the juice being set on the shelf of a water-bath, and exposed to a proper temperature, will furnish in a short time a large quantity of medicinal extract, possessing the properties of the plant unimpaired.

For exceedingly delicate purposes, the concentration may be performed in the cold, by placing saucers filled with the expressed juice over a basin containing sulphuric acid, putting a glass receiver over them, and exhausting its air.

The use of the air-pump for evaporating such chemical substances as are readily injured by heat, has been very common since Professor Leslie's discovery of the efficacy of the combined influence of rarefied air and an absorbing surface of sulphuric acid in evaporating water at low temperatures. It has been supposed that the virtues of narcotic plants in particular might be better obtained and preserved by evaporation in vacuo than otherwise, as the decomposing agency of heat and atmospheric oxygen would be thereby excluded. There is no doubt that extracts thus made from the expressed juices of fresh vegetables possess for some time at least, the green aspect and odour of the plants in far greater perfection than those usually made in the air, with the aid of artificial heat. Dr. Meurer, in the *Archiv. der Pharmacie* for April, 1843, has endeavoured to show that the colour and odour are of no use in determining the value of extracts of narcotics, that the albumen left unchanged in the extracts made in vacuo, tends to cause their spontaneous decomposition, and that the extracts made with the aid of alcohol, as is the practice in Germany, are more efficacious at first, and much less apt to be injured by keeping. M. Baldenius has, in the same number of the *Archiv.*, detailed experiments to prove that the juices of recent plants mixed with alcohol, in the homœopathic fashion, are very liable to spontaneous decomposition. To the above expressed juice, the Germans add the alcoholic tincture of the residuary vegetable matter, and evaporating both together, prepare very powerful extracts.

F.

FACETTING. The process of cutting faces upon ornamental articles. Steel jewellery, such as beads, studs, buttons,—the ornaments on the hilts of dress-swords and similar objects, are ground on horizontal laps with fine emery. Facets on gold and silver are cut and polished on revolving wheels, after the same general method as that pursued by the lapidary for cutting facets on stones.

FACTORY. In the sense in which this term is introduced here, it is contracted from manufactory; meaning the place where workmen are employed in fabricating goods. To describe all the various factories, would be to describe all the different manufactures, or, at least, the arrangements of the machines by which the raw material is converted into marketable goods. There is but one kind of factory which will be described in this place. The arrangements of a cotton factory fairly represent all the arrangements for other branches of textile manufactures, and here this is specially described. Under SILK, WOOL, &c., will be found particulars of the machines used and their general arrangements in these factories respectively.

FACTORY, COTTON *(General Construction of)*. There is no textile substance whose filaments are so susceptible of being spun into fine threads of uniform twist, strength, and diameter, as cotton wool. It derives this property from the smoothness, tenacity, flexibility, elasticity, peculiar length, and spiral form of the filaments; hence, when a few of them are pulled from a heap with the fingers and thumb, they lay hold of and draw out many others. Were they much longer they could not be so readily attenuated into a fine thread, and were they much shorter the thread would be deficient in cohesion. Even the differences in the lengths of the cotton staple are of advantage in adapting them to different styles of spinning and different textures of cloth.

If we take a tuft of cotton wool in the left hand, and seizing the projecting fibres with the right, slowly draw them out, we shall perceive with what remarkable facility

they glide past each other, and yet retain their mutual connection, while they are extended and arranged in parallel lines, so as to form a little riband susceptible of considerable elongation. This demonstration of the ductility, so to speak, of cotton wool, succeeds still better upon the carded fleece in which the filaments have acquired a certain parallelism; for in this case the tiny riband, in being drawn out by the fingers to a moderate length, may at the same time receive a gentle twist to preserve its cohesion till it becomes a fine thread.

Hence we may imagine the steps to be taken or the mechanical processes to be pursued in cotton spinning. After freeing the wool of the plant from all foreign substances of a lighter or a heavier nature, the next thing is to arrange the filaments in lines as parallel as possible, then to extend them into regular ribands, to elongate these ribands by many successive draughts, doubling, quadrupling, or even octupling them meanwhile, so as to give them perfect equality of size, consistence and texture, and at the same time to complete the parallelism of the fibres by undoing the natural convolutions they possess in the pod. When the rectilinear extension has been thus carried to the fineness required by the spinner, or to that compatible with the staple, a slight degree of torsion must accompany the further attenuation; which torsion may be either momentary, as in the tube roving machine, or permanent, as in the bobbin and fly frame. Finally, the now greatly attenuated soft thread, called a *fine roving*, is drawn out and twisted into finished cotton yarn, either by continuous indefinite gradations of drawing and twisting, as in the throstle, or by successive stretches and torsions of considerable lengths at a time, as in the mule.

Mechanical spinning consists in the suitable execution of these different processes by a series of different machines. After the carding operation, these are made to act simultaneously upon a multitude of ribands and spongy cords or threads by a multitude of mechanical hands and fingers. However simple and natural the above described course of manufacture may appear to be, innumerable difficulties stood for ages in the way of its accomplishment; and so formidable were they as to render their entire removal of late years in the cotton factories of England one of the greatest and most honourable achievements of human genius.

The various operations may be thus classified for fine spinning:—

1. The *mixing* and opening up or loosening the flocks of cotton wool, as imported in the bags, so as to separate at once the coarser and heavier impurities as well as those of a lighter and finer kind.

2. The *willowing*, *scutching* or *blowing*, and *lapping*, to remove seeds and dirt, and prepare the material in the form of a continuous lap or sheet for the next operation of

3. The *carding*, which is intended to disentangle every tuft or knot, to remove every remaining impurity which might have eluded the previous operation, and finally to prepare for arranging the fibres in parallel lines, by laying the cotton first in a fleecy web, and then in a riband form.

4. The *doubling* and *drawing out* of the card-ends or ribands, in order to complete the parallelism of the filaments, and to equalise their quality and texture.

5. The *roving* operation, whereby the *drawings* made in the preceding process are greatly attenuated, with no more twist than is indispensable to preserve the uniform continuity of the spongy cords.

6. The *fine roving* and *stretching* come next; the former operation being effected by the fine bobbin and fly frame, the latter by the stretcher mule.

7. The *spinning* operation finishes the extension and twist of the yarn, and is done either in a continuous manner by the throstle, or discontinuously by the mule: in the former, the yarn is progressively drawn, twisted, and wound upon the bobbins; in the latter, it is drawn out and twisted in lengths of from 56 to 67 inches, which are then wound all at once upon the spindles.

8. The eighth operation is the *winding*, *doubling*, and *singeing* of the yarns, to fit them for the muslin, the stocking, or the bobbin net lace manufacture.

9. The *packing press*, for making up the yarn into bundles for the market, concludes this series.

Note. — Yarns spun for weaving into cloth, as named in the 8th operation, after being wound, are at once warped, and after being sized, or dressed, are ready for the loom.

10. To the above may be added the operations of the dressing machines, for fine warps; the tape leg machine, for medium counts of warps, say 24*s.* to 50*s.*, and sizing troughs for warps of coarser counts.

11. The power looms.

12. The plaiting, or folding and measuring machine.

13. The press for compressing the bundles of cloth ready for delivery.

The site of the factory ought to be carefully selected in reference to the health of the

operatives, the cheapness of provisions, the facilities of transport for the raw materials, and the convenience of a market for the manufactured articles. An abundant supply of labour, as well as fuel and water for mechanical power, ought to be primary considerations in setting down a factory. It should therefore be placed, if possible, in a populous village, near a river or canal, but in a situation free from marsh malaria, and with such a slope to the voider stream as may ensure the ready discharge of all liquid impurities. These circumstances happily conspire in the districts of Stockport, Hyde, Staleybridge, Dukenfield, Bury, Blackburn, &c., and have eminently favoured the rapid extension of the cotton manufactures for which these places are pre-eminent.

The better to illustrate the above-named requisites for cotton spinning and manufacturing, we proceed to a description of a mill at Stockport, Lancashire, containing the large number of 61,400 throstle and mule spindles, and 1320 power looms.

Mr. R. M'Clure's Cotton Factory.—The mill consists of a main body with two lateral wings, projecting forwards, the latter being appropriated to store-rooms, a counting-house, rooms for winding the yarn on bobbins, and other miscellaneous purposes. The building has six floors besides the attic story. The ground-plan comprehends a plot of ground 280 feet long by 200 broad, exclusive of the boiler sheds.

The right-hand end, A (*fig.* 733) of the principal building, is separated from the main body by a strong wall, and serves in the three lower stories for accommodating two ninety-horse steam engines, which are supplied with steam from a range of boilers contained in a low shed exterior to the mill.

The three upper stories over the steam engine gallery are used for unpacking, sorting, picking, cleaning, willowing, and lapping the cotton wool. Here are the willow, the blowing, and the lap machines, in a descending order, so that the lap machine occupies the lowest of the three floors, being thus most judiciously placed on the same level with the preparation room of the building. On the fourth main floor of the factory there are, in the first place, a line of carding engines arranged, near and parallel to the windows, as shown at B B, in the ground plan (*fig.* 733), and, in the second place, two rows of drawing frames, and two of bobbin and fly frames, in alternate lines, parallel to each other, as indicated by D, C, D, C, for the drawing frames, and E, E, E, E, for the bobbin and fly frames in the ground plan. The latter machines are close to the centre of the apartment.

The two stories next *under* the preparation room are occupied with throstle frames, distributed as shown at F F, in the ground plan. They stand in pairs alongside of each other, whereby two may be tended by one person. These principal rooms are 280 feet long, and nearly 50 feet wide. The two stories, *over* the preparation room, viz., the fifth and sixth floors from the ground, are appropriated to the mule jennies, which are placed in pairs fronting each other, so that each pair may be worked by one man. Their mode of distribution is shown at G G, in the ground plan. The last single mule is seen standing against the end wall, with its head-stock projecting in the middle.

The ground floor of the main building, as well as the extensive shed abutting behind it, marked by N, H, H, in the plan, is devoted to the power looms, the mode of placing which in plainly seen at H, H, H.

The attic story accommodates the winding frames, and warping mills, and the warp sizing machines, subservient to power weaving.

Some extra mules (self-actors), are placed in the wings.

We shall briefly sum up the references in the ground plan as follows:—

A, the ground apartment for the steam engines.

B, the distribution of the carding engines, the moving shaft or axis running in a straight line through them, with its pulleys, for receiving the driving bands.

C C, the drawing frames.

D D, the jack, or coarse bobbin and fly frames.

E E, the fine roving, or bobbin and fly frames.

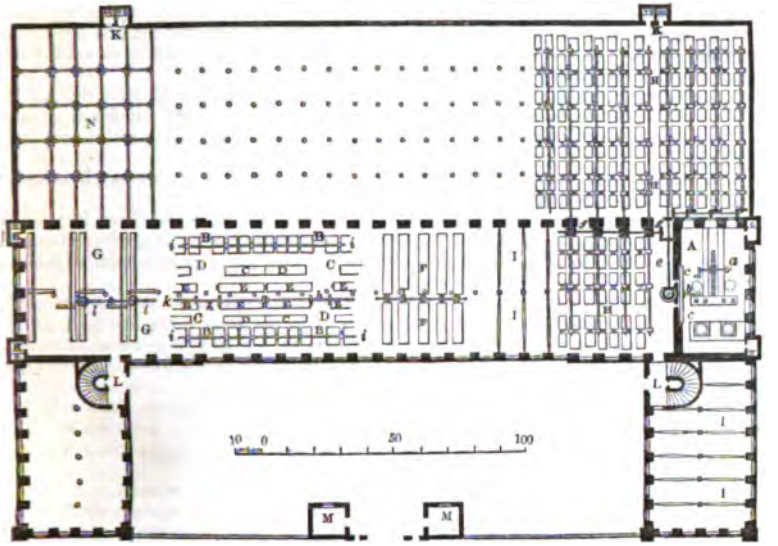
F, the arrangement of the throstle frames, standing in pairs athwart the gallery, in the 2nd and 3rd flats.

G, the mules are here represented by their roller beams, and the outlines of their head-stocks, as placed in the 5th and 6th stories.

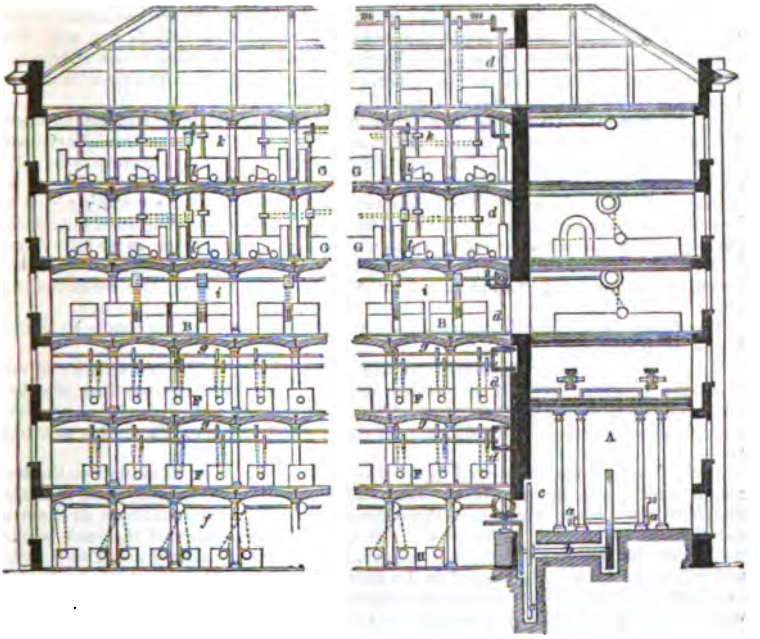
H, the looms, with their driving pulleys projecting from the ends of their main axes. Sometimes the looms are placed in parallel straight lines, with the rigger pulleys of the one alternately projected more than the other, to permit the free play of the driving-belts; sometimes the looms are placed, as generally in this engraving, alternately to the right and left, by a small space, when the pulleys may all project equally. The former plan is the one adopted in Mr. Orrell's mill.

I, represents the cast-iron girders which support the floors of this fire-proof building.

733



734



K, K, are closets placed in each floor, in the recesses of a kind of pilasters built against the outside of the edifice. These hollow shafts are joined at top by horizontal pipes, which all terminate in a chest connected with the suction axes of a fan, whereby a constant draught of air circulates up the shafts, ventilates the apartments, and prevents the reflux of offensive effluvia from the water-closets, however careless the work-people may be. The closets towards the one end of the building are destined for the men; towards the other for the women.

L, L, are the staircases, of a horse-shoe form, the interior space or shaft in the middle being used for the teagle or hoist. In the posterior part of the shaft a niche or groove is left for the counter-weight to slide in, out of the way of the ascending and descending platform.

M, M, are the two porters' lodges, connected to the corner of each wing by a handsome iron balustrade. They are joined by an iron gate.

It will be observed that the back loom-shed has only one story, as shown in section (*fig.* 735). In the ground plan of the shed, N represents the roofing, of wood-work. The rafters of the floors rest at their ends upon an iron plate, or shoe with edges (as it is called), for the girders to bear upon.

Two steam engines, of fully 100 horse-power each, and two of 50 horse-power each, operate by cranks, which stand at right angles upon the shaft marked *a* both in the plan and section. In the centre, between the bearings, is a large cog-wheel, driving a smaller one upon the shaft marked *b* in both figures, to which the fly-wheel *c* belongs. That prime motion wheel is magnificent, and possesses a strength equal to a strain of 300 horses. From this shaft motion is given to the main or upright shaft *d*, in the section, by two bevel wheels, visible at the side and on the top of the great block of stone, about 5 tons weight (*fig.* 733), which gives a solid basis to the whole moving apparatus.

The velocity of the piston in these steam engines is 240 ft. per minute.

The first shaft makes 44·3 revolutions per minute; the main upright shaft 58·84 per minute. The steam engine makes 16 strokes per minute; and the length of their stroke is 7 ft. 6 in.

As the one engine exerts its maximum force when the other has no force at all, and as the one increases as the other diminishes in the course of each pair of strokes, the two thus co-operate in imparting an equable impulsion to the great gearing and shafts, which, being truly made, highly polished, and placed in smooth bearings of hard brass, revolve most silently and without those vibrations which so regularly recurred in the old factories, and proved so detrimental to the accurate performance of delicate spinning frames.

The steam for these four engines is supplied by four high pressure horizontal engines, made by B. Goodfellow of Hyde, the exhausted steam from which has still power enough to drive the low pressure condensing engines. By an ingenious arrangement the condensing water from these engines, while on its return to the river is made to turn an 8 horse water-wheel.

A 12-horse auxiliary engine for driving the warping mills, sizing and drying frames, and mechanic's shop at night (in the event of breakages to the machinery), completes the power of this great mill, equalling over 1000 indicated horse-power, all the steam being supplied by 5 boilers carrying 70 lbs. pressure.

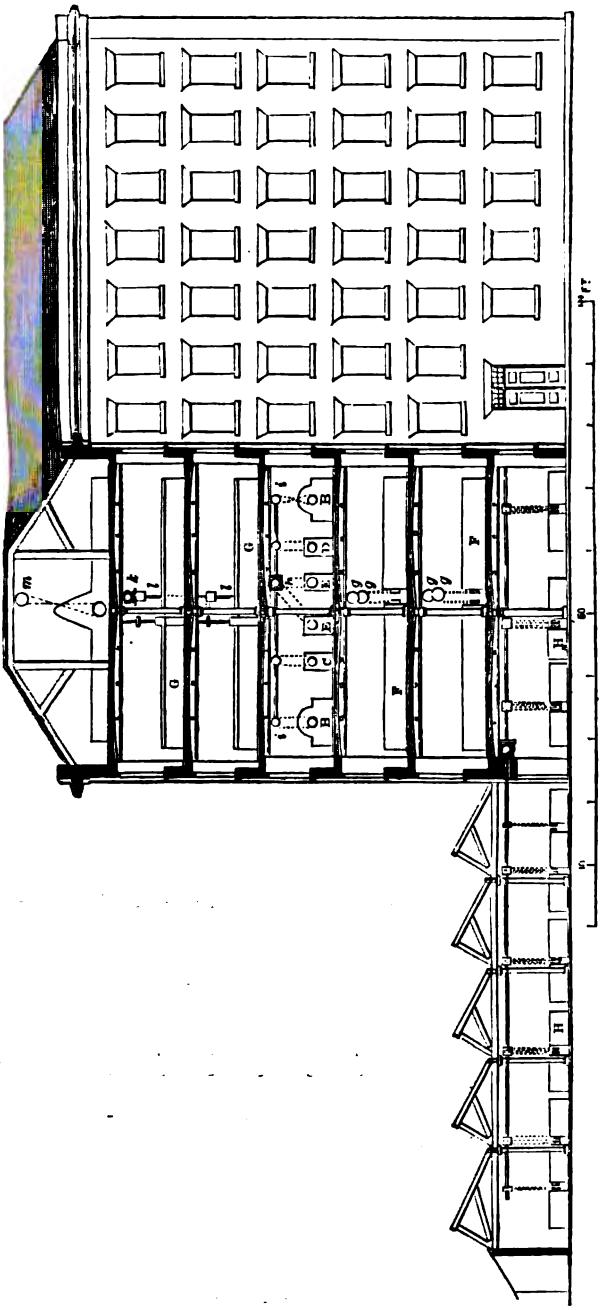
Note.—Prior to the application of the principle of compounding or uniting high and low-pressure engines, the above-named four low pressure engines required nine boilers, carrying 14 lbs. pressure, to supply them with sufficient steam; now, as we have shown, boilers of smaller dimensions, carrying 70lbs. pressure, supply a sufficient quantity of steam, for increased power, at a reduction of fifty per cent. on the consumption of coals.

The power for driving the machinery is conveyed from the engine rooms by shafting in the usual manner.

To the horizontal ramifications from the upright shaft any desired velocity of rotation may be given by duly proportioning the diameters of the bevelled wheels of communication between them; thus, if the wheel on the end of the horizontal shaft have one-half or one-third the diameter of the other, it will give it a double or a triple speed.

In the lowest floor, the second bevel wheel above the stone block drives the horizontal shaft *e*, seen in the ground plan; and thereby the horizontal shaft *f*, at right angles to the former, which runs throughout the length of the building, as the other did through its breadth, backwards. The shaft *f* lies alongside of the back window wall, near the ceiling; and from it the transverse slender shafts proceed to the right and left in the main building, and to the shed behind it, each of them serving to drive two lines of looms. These slender or branch shafts are mounted with pulleys, each of which drives four looms by four separate bands.

785



In the second and third floors, where the throstles are placed, the shaft *d* is seen in the section to drive the following shafts :—

Upon the main upright shaft *d* (*fig.* 735), there are in each of these stories two horizontal bevel wheels, with their faces fronting each other (shown plainly over *d d*), by which are moved two smaller vertical bevel wheels, on whose respective axes are two parallel shafts, one over each other, *g g*, which traverse the whole length of the building. These two shafts move therefore with equal velocities, and in opposite directions. They run along the middle space of each apartment; and wherever they pass the rectangular line of two throstle frames (as shown at F in the ground plan) they are each provided with a pulley; while the steam pulleys on the axes of two contiguous throstles in one line are placed as far apart as the two diameters of the said shaft-pulleys. An endless strap goes from the pulley of the uppermost horizontal shaft round the steam or driving-pulley of one throstle frame; then up over the pulley *g*, the second or lower shaft, *g*; next up over the steam pulley of a second throstle; and, lastly, up to the pulley of the top shaft, *g*. See *g g* in the throstle floors of the cross section.

In the preparation room, three horizontal shafts are led pretty close to the ceiling through the whole length of the building. The middle one, *h* (see the plan, *fig.* 733), is driven immediately by bevel wheels from the main upright shaft *d* (*fig.* 734). The two side ones *i*, *i*, which run near the window walls, are driven by two horizontal shafts, which lead to these side shafts. The latter are mounted with pulleys, in correspondence with the steam pulleys of the two lines of carding engines, as seen between the cards in the plan. The middle shaft *h*, drives the two lines of bobbin and fly frames, E, E, E, E (see cross section), and short shafts *i*, *i*, seen in the cross section of this floor, moved from the middle shaft *h*, turning the gallows fixed to the ceiling, over the drawing and jack frames, give motion to the latter two sets of machines. See C D in the cross section.

To drive the mules in the uppermost story, a horizontal shaft *k* (see longitudinal and cross sections, as well as ground plan) runs through the middle line of the building, and receives motion from bevel wheels placed on the main upright shaft, *d*, immediately beneath the ceiling of the uppermost story. From that horizontal shaft, *k*, at every second mule, a slender upright shaft, *l*, passing through both stories, is driven (see both sections). Upon these upright branch shafts are pulleys in each story, one of which serves for two mules, standing back to back against each other. To the single mules at the ends of the rooms, the motions are given by still slenderer upright shafts, which stand upon the head stocks, and drive them by wheel-work, the steps (top bearings) of the shafts being fixed to brackets in the ceiling.

In the attic, a horizontal shaft *m m*, runs lengthwise near the middle of the roof, and is driven by wheel-work from the upright shaft. This shaft, *m*, gives motion to the warping mills and dressing machines.

This cotton mill having been erected according to plans devised and executed by that very eminent engineer, Mr. Fairbairn, of Manchester, may be justly reckoned a model of factory architecture. It is mounted with 1320 power-looms, of which each 100 require steam power equivalent to 25 horses to impel them, inclusive of the preparation and spinning operations competent to supply the looms with yarn.

Ten looms, with the requisite dressing, without spinning, are considered to be equivalent to 1 horse power in a steam engine. Steam power equivalent to 1 horse will drive—

500 mule spindles,
300 self-actor spindles,
180 throstle spindles of the common construction; in which estimate the requisite preparation processes are included.

In Mr. M'Clure's mill there are in the throstle-frame floors - - - - - - - - -	27,200	spindles
And in the mule floors - - - - - - - -	34,200	"
Total yarn spindles -	61,400	

To which add, power-looms 1320, producing the product of the spindles, in the shape of 300,000 yards of cloth in every week of 60 hours.

One of the most compact and best regulated modern factories, on the small scale, which we visited in Lancashire, consisted of the following system of machines :—

1 willow, 1 blowing machine, 1 lap machine, capable, together, of cleansing and lapping 9000 pounds of cotton per week, if required.
21 cards, breakers, and finishers, which carded 5000 lbs. of cotton every week of 60 hours' work, being about 240 lbs. per card.
3 drawing-frames, of 3 heads each.

3 coarse bobbin and fly frames.
7 fine bobbin and fly frames. No stretcher mule.
12 self-actor mules, of Sharp and Roberts's construction, of 404 spindles each =4848 mule spindles.
10 throstle frames, of 236 spindles each =2360 spindles.
7 dressing machines.
236 power-looms.
2 warping mills.
300 winding spindles for winding the warp.

The rovings have 4 hanks in the pound, and are spun into yarn No. 38 on the throstle, as well as the mule.

One bobbin of the roving (compressed) lasts 5 days on the self-actors, and 6 days on the throstles.

According to the estimate of Peel and Williams, of Manchester, 66 horses power of a steam engine are equivalent to 396 power-looms, including 16 dressing machines; the cloth being 36 inches wide upon the average, and the yarn varying in fineness from 12's to 40's, the mean being 26's. Here, the spinning and preparation not being included, the allowance of power will appear to be high. The estimate given above assigns 10 looms, with the requisite dressing, to 1 horse; but the latter assigns no more than 6.

For the following experimental results, carefully made with an improved steam engine *indicator*, upon the principle of Mr. Watt's construction, we are indebted to Mr. Bennet, an engineer in Manchester. His mode of proceeding was to determine, first of all, the power exerted by the factory steam engine when all the machines of the various floors were in action; then to detach, or throw out of gear, each system of machines, and to note the diminution of force now exercised. Finally, when all the machines were disengaged, he determined the power requisite to move the engine itself as well as the great gearing-wheels and shafts of the factory.

He found at the factory of J. A. Beaver, Esq., in Manchester, that 500 calico looms (without dressing) took the power of 33 horses, which assigns 15 looms to 1 horse power.

At Messrs. Birley's factory, in Manchester, he found that 1080 spindles in 3 self-actor mules took 2·59 horses, being 417 spindles for 1 horse power; that 3960 spindles in 11 self-actors took 8·33 horses, being 475 spindles per horse power; 1,080 spindles in 3 self-actors took 2 horses, being 540 spindles per horse.

At Messrs. Clarke and Sons, in Manchester, that 585 looms in weaving fustians of various breadths took 54 horses power, exclusive of dressing machines, being 11 looms to 1 horse.

At J. A. Beaver's, on another occasion, he found that 1200 spindles, of Danforth's construction, took 21 horses, being 57 spindles per horse power; and that in a second trial the power of 22 horses was required for the same effect, being 54 Danforth's spindles per horse power.

An excellent engine of Messrs. Boulton and Watt, being tried by the indicator, afforded the following results in a factory: —

A 60 horse boat-engine (made as for a steam boat) took 14½ horses power to drive the engine with the shafts	14·5
3½ blowing machines, with their 3 fans - - -	21·55
10 dressing machines - - - - - -	10·25
12 self-actor mules of 360 spindles each (720 spindles per horse power) - - - - - -	6·00
6 Danforth's throstle frames, containing 570 spindles (96 in each), being 93 spindles to 1 horse power -	6·20

At Bollington, in a worsted mill, he found that 106½ spindles, including preparation, took 1 horse power upon throstles. N. B. There is no carding in the long wool or worsted manufacture for merinos.

At Bradford, in Yorkshire, he found that a 40 horse power boat-engine, of Boulton and Watt's, drove 598 calico looms, 6 dressing machines (equivalent to dress warp for 180 of the said looms), and 1 mechanics' workshop, which took 2 horses power. Other engineers estimate 200 common throstle spindles, by themselves, to be equivalent to the power of 1 horse.

The shafts which drive the cards revolve about 120 times per minute, with a driving pulley of from 15 to 17 inches in diameter.

The shafts of the drawing and the bobbin and fly frames revolve from 160 to 200 times per minute, with pulleys from 18 to 24 inches in diameter.

The shafts of throstle frames in general turn at the rate of from 220 to 240 times per

minute, with driving pulleys 18 inches in diameter, when they are spinning yarn of from No. 35 to 40. The shafts of mules revolve about 130 times per minute, with pulley 16 inches in diameter.

The shafts of power looms revolve from 110 to 120 times per minute, with pulleys 15 inches in diameter.

The shafts of dressing machines revolve 60 times per minute, with pulleys 14 inches in diameter.

Before quitting the generalities of the cotton manufacture we may state the following facts communicated also by Mr. Bennet: —

A waggon-shaped boiler, well set, will evaporate 12 cubic ft. of water with 1 cwt. of coals; and a steam-boiler with winding flues will evaporate 17 cubic ft. with the same weight of fuel: $7\frac{1}{10}$ lbs. of coals of the former boiler are equivalent to 1 horse power exerted for an hour, estimating that a horse can raise 33,000 lbs. 1 foot high in a minute.

The first cotton mill upon the fire-proof plan was erected by the Messrs. Strutt, at Belper, in the year 1797; that of Messrs. Phillips and Lee, at Manchester, in 1801; that of H. Houldsworth, Esq., of Glasgow, in 1802; and that of James Kennedy, at Manchester, in 1805; since which time many good factories have been built fire-proof, like Mr. M'Clure's.

The heating of the apartments of cotton factories is effected by a due distribution of cast-iron pipes, of about 7 or 8 inches diameter, which are usually suspended a little way below the ceilings, traverse the rooms in their whole length, and are filled with steam from boilers exterior to the building. It has been ascertained that one cubic foot of boiler will heat fully more than 2,000 cubic ft. of space in a cotton mill, and maintain it at the temperature of about 75° Fahr. If we reckon 25 cubic ft. contents of water in a waggon-shaped steam boiler as equivalent to 1 horse power, such a boiler would be capable of warming 50,000 cubic ft. of space; and therefore a 10 horse steam boiler will be able to heat 500,000 cubic ft. of air from the average temperature, 50°, of our climate, up to 75°, or perhaps even 80° Fahr.

It has been also ascertained that in a well-built cotton mill, one superficial foot of exterior surface of cast-iron steam pipe will warm 200 cubic ft. of air. In common cases for heating churches and public rooms, we believe that one-half of the above heating surface will be found adequate to produce a sufficiently genial temperature in the air. The temperature of the steam is supposed to be the same with that in Mr. Watt's low-pressure engines, only a few degrees above 212°—the boiling point of water.

The pipes must be freely slung, and left at liberty to expand and contract under the changes of temperature, having one end at least connected with a flexible pipe of copper or wrought iron, of a swan-neck shape. Through this pipe the water of condensation is allowed to run off. The pipes should not be laid in a horizontal direction, but have a sufficient slope to discharge the water. The pipes are cast from half an inch to three-quarters thick in the metal. In practice the expansion of steam pipes of cast-iron may be taken at about one-tenth of an inch in a length of 10 feet, when they are heated from a little above the freezing to the boiling point of water. The upper surface of a horizontal steam pipe is apt to become hotter than the bottom, of the water be allowed to stagnate in it; the difference being occasionally so great, as to cause a pipe 60 feet long to be bent up two inches in the middle.

In arranging the steam pipes provision ought to be made not only for the discharge of the water of condensation, as above stated, but for the ready escape of the air; otherwise the steam will not enter freely. Even after the pipes are filled with steam, a little of it should be allowed to escape at some extreme orifice, to prevent the re-accumulation of air discharged from the water of the steam boiler. In consequence of water being left in the pipes serious accidents may happen; for the next time the steam is admitted into them, the regularity of heating and expansion is impeded, some part of the pipe may crack, or a violent explosion may take place, and the joints may be racked to a very considerable distance, every way, from the place of rupture, by the alternate expansions and condensations. The pipes should therefore be laid, so as to have the least possible declivity, in the direction of the motion of the steam.

Formerly, when drying rooms in calico printing works were heated by iron stoves, or cockles, their inmates were very unhealthy, and became emaciated; since they have been heated by steam pipes the health of the people has become remarkably good, and their appearance frequently blooming.

Factory is also a place where factors meet to dispose of goods, as Tea factories, &c. &c.

FAHLERZ. Grey copper-ore, called also *Panabase*, from the many oxides it contains, and *Tetrahedrite* from its form.

The analysis of a crystalised specimen from Huel Prosper, in Cornwall, gave

Copper	30·18	Antimony	23·66
Silver	traces	Arsenic	4·40
Iron	6·99	Sulphur	25·04
Zinc	traces		

Specimens from Baden and Freiberg have been found to contain as much as from 18 to 31 per cent. of silver. The following analysis by M. Rose, of grey copper ore, or Fahlerz, will show the variation in composition of this interesting mineral : —

	Sulphur.	Antimony.	Copper.
1. St. Marie Auxillines, in Alsace	26·83	12·46	40·60
2. Gersdorf, Freiburg	26·33	16·52	38·63
3. Kapnik, Hungary	25·77	23·94	37·98
4. Dillenburg, in Nassau	25·03	25·27	38·42
5. Mine Zidda, at Clausthal	24·73	28 24	34·48
6. Mine Wenzel, near Wolfnach, Baden	23·52	26·63	25·23
7. Mine Kabacht, near Freiburg	21·17	24·63	14·81

Besides Arsenic, Iron, Zinc, and Silver.

FAINTS is the name of the impure spirit which comes over first and last in the distillation of whiskey; the former being called the *strong*, and the latter, which is much more abundant, the *weak* faints. This crude spirit is much impregnated with fœtid essential oil (fusel oil), it is therefore very unwholesome, and must be purified by rectification.

FALSE TOPAZ. A light yellow pellucid variety of quartz crystal. It may be distinguished from yellow topaz, for which when cut it is frequently substituted, by its difference of crystalline form, the absence of cleavage, inferior hardness, and lower specific gravity. Found in the Brazils, &c.

FAN (*Eventail*, Fr.; *Fächer*. Germ.) is usually a semi-circular piece of silk or paper, pasted double, enclosing slender slips of wood, ivory, tortoise-shell, whale-bone, &c., arranged like the tail of a peacock in a radiating form, and susceptible of being folded together, and expanded at pleasure. This well-known hand ornament is used by ladies to cool their faces by agitating the air. Fans made of feathers, like the wing of a bird, have been employed from time immemorial by the natives of tropical countries.

Fan is also the name of the apparatus for winnowing corn, for urging the fires of furnaces, and for purposes of ventilation. For an account of the powerful blowing and ventilating fan machines, see FOUNDRY and VENTILATOR.

FANG, *a mining term*. A niche cut in the side of an adit or shaft, to serve as an air course. Sometimes the term *a fanging* is applied to a main of wood pipes.

FARINA (*Farine*, Fr.; *Mehl*, Germ.) is the flower of any species of corn, or starchy root, such as potato, arrow-root, &c. See BREAD and STARCH.

FATS (*Graisses*, Fr.; *Fette*, Germ.) occur in a great number of the animal tissues, being abundant under the skin in what is called the cellular membrane, round the kidneys, in the folds of the omentum, at the base of the heart, in the mediastinum, the mesenteric web, as well as upon the surface of the intestines, and among many of the muscles. Fats vary in consistence, colour, and smell, according to the animals from which they are obtained; thus, they are generally fluid in the cetaceous tribes, soft and rank-flavoured in the carnivorous, solid and nearly scentless in the ruminants, usually white and copious in well-fed young animals; yellowish and more scanty in the old. Their consistence varies also according to the organ of their production; being firmer under the skin and in the neighbourhood of the kidneys than among the movable viscera. Fat forms about one-twentieth of the weight of a healthy animal. But as taken out by the butcher it is not pure; for being of a vesicular structure it is always enclosed in membranes, mixed with blood, blood-vessels, lymphatics, &c. These foreign matters must first be separated in some measure mechanically, after the fat is minced small, and then more completely by melting it with hot water, passing it through a sieve, and letting the whole cool very slowly. By this means a cake of cleansed fat will be obtained.

Braconnot and Raspail have shown that solid animal fats are composed of very small microscopic, partly polygonal, partly reniform particles, which are connected together by very thin membranes. These may be ruptured by mechanical means, then separated by triturating the fresh fats with cold water, and passing the unctuous matter through a sieve. The particles float in the water, but eventually collect in a white

granular crystalline appearance, like starch. Each of them consists of a vesicular integument, of the nature of stearine, and an interior fluid like elaine, which afterwards exudes. The granules float in the water, but subside in spirits of wine. When digested in strong alcohol, the liquid part dissolves, but the solid remains. These particles differ in shape and size, as obtained from different animals; those of the calf, ox, sheep, are polygonal, and from $\frac{1}{50}$ to $\frac{1}{150}$ of an inch in diameter; those of the sow are kidney-shaped, and from $\frac{1}{50}$ to $\frac{1}{100}$; those of man are polygonal, and from $\frac{1}{75}$ to $\frac{1}{300}$; those of insects are spherical, and at most $\frac{1}{500}$ of an inch.

Fats all melt at a temperature much under 212° F. When strongly heated with contact of air, they diffuse white pungent fumes, then blacken, and take fire. When subjected to distillation they afford a changed fluid oil, carburetted hydrogen, and the other products of oily bodies. Exposed for a certain time to the atmosphere, they become rancid, and generate the same fat acid as they do by saponification. In their fresh state they are all composed principally of stearine, margarine, and oleine, with a little colouring and odorous matter; and in some species, hircine, from the goat; phocenine, from the dolphin; and butyrine from butter. By subjecting them to a great degree of cold, and compressing them between the folds of blotting paper, a residuum is obtained, consisting chiefly of stearine and margarine; the latter of which may be dissolved out by oil of turpentine.

Beef and Mutton Suet.—When fresh, this is an insipid, nearly inodorous fat, of a firm consistence, almost insoluble in alcohol, entirely so, if taken from the kidneys and mesenteric web of the ox, the sheep, the goat, and the stag. It varies in its whiteness consistence, and combustibility, with the species and health of the animals. They may all be purified in the manner above described. Strong sulphuric acid developes readily the acid fats by stirring it through melted suet. Alkalies, by saponification, give rise to one of the three acids,—the stearic, margaric, or oleic. Beef suet consists of stearine, margarine, and oleine; mutton and goat suet contain a little hircine. The specific gravity of the tallow of which common candles are made is, by Ure's experiments, 0·936. The melting point of suet is from 98° to 104° F. The proportion of solid and fluid fat in it is somewhat variable, but the former is in much larger proportion. Mutton suet is soluble in 44 parts of boiling alcohol, of 0·820; beef suet in 44 parts. Marrow fat consists of 76 of stearine, and 24 of oleine; it melts at 115° F.

Hog's lard is soft, fusible at 81° F., convertible, by an alkaline solution, into a stearate, margarate, oleate, and glycerine. Its sp. grav, is 0·938, at 50° F. It consists of 62 of oleine, and 38 of stearine, in 100 parts.

Goose-fat consists of 68 oleine and 32 stearine.

Butter, in summer consists of 60 of oleine and 40 of stearine; in winter, of 35 of oleine, and 65 of stearine; the former substance being yellow and the other white. It differs, however, as produced from the milk of different cows, and also according to their pasture.

The ultimate constituents of stearine, according to Chevreul, are, 79 carbon; 11·7 hydrogen; and 9·3 oxygen in 100 parts.

See MARGARINE, OLEINE, SOAP, STEARINE.

The following statement is given on the authority of Braconnot:—

	Oleine.	Stearine.
Fresh butter in summer	60	40
——— in winter	37	63
Hog's lard	62	38
Ox marrow	24	76
Goose fat	68	32
Duck fat	72	28
Ox tallow	25	75
Mutton suet	26	74

Dr. Robert Dundas Thomson has given the following list of animal fats and their melting points:—

Badger fat	86°	Duck's fat	77°
Beef tallow	98½	Dog	79¾
Calf	136·8	Fox	129
Camel	131	Hare	117½
Cochineal fat	104	Hog's lard	80·5
Cow's butter	79·7	Horse grease	140

Human fat	77°	Stearine (duck)	109°
Pheasant	109	Cetine	120
Turkey	113	Chlorestine	278
Stearine (human)	120	Cantharides fat	93½
„ (sheep)	109	Margarine (butter)	105
„ (oxen)	111	Palmitine	115
„ (hog)	109		

M. Dumas says that butter contains no stearine. The purification and decoloration of fats has been the object of many patents. One of the best is to mix two per cent. of strong sulphuric acid with a quantity of water, in which the tallow is heated for some time with much stirring; to allow the materials to cool, to take off the supernatant fat, and to re-melt it with abundance of hot water. More tallow will thus be obtained, and that considerably whiter and harder than is usually procured by the melters.

Dr. Ure states that he has found that chlorine and chloride of lime do not improve, but rather deteriorate, the appearances of oils and other fatty bodies. According to Appert, minced suet subjected to the action of high-pressure steam in a digester, at 250° or 260° F., becomes so hard as to be sonorous when struck, whiter, and capable when made into candles, of giving a superior light. A convenient mode of *rendering* minced tallow, or melting it, is to put it in a tub, and drive steam through it from numerous orifices in ramifying pipes placed near the bottom. Mr. Watt's plan of purifying fats, patented in March, 1836, has been successful. He employs dilute sulphuric acid, to which he adds a little nitric acid, with a very small quantity of bichromate of potash, to "supply oxygen," and some oxalic acid. These are mixed with the fat in the steaming tub. When the lumps of it are nearly dissolved, he takes for every ton of fat, one pound of strong nitric acid, diluted with one quart of water; to which he adds two ounces of alcohol, naphtha, sulphuric ether, or spirits of turpentine; and after introducing this mixture, he continues the boiling for half an hour. The fat is finally washed.

Others have proposed to use vegetable or animal charcoal first, especially for rancid oils, then to heat them with a solution of sulphate of copper and common salt, which is supposed to precipitate the fetid albuminous matter.

Mr. Prynne obtained a patent in March, 1840, for purifying tallow for the candle-maker, by heating it along with a solution of carbonate of potash or soda for 8 hours, letting the whole cool, removing the tallow to another vessel, heating it by means of steam up to 206° F., along with dry carbonate of potash (pearlash): letting this mixture cool very slowly; and finally removing the tallow to a vessel inclosed in steam, so as to expel any subsidiary moisture. — *Newton's Journal*, xxi. 258.

A patent for a like purpose was obtained in June, 1842, by Mr. H. H. Watson. He avails himself of the blanching power of oxygen, as evolved from permanganate of potash (chameleon mineral), in the act of its decomposition by acids, while in contact with the melted fat. He prescribes a leaden vessel (a well joined wooden tub will also serve) for operating upon the melted tallow with one-twentieth of its weight of the manganate dissolved in water, and acidulated to the taste. The whole are to be well mixed, and gradually heated from 150° up to 212° F., and maintained at that temperature for an hour. On account of the tendency of the dissolved manganate to spontaneous decomposition, it should be added to the dilute acid, mixed with the fat previously melted at the lowest temperature consistent with its fluidity.

Mr. Wilson, of Vauxhall, has applied centrifugal action to the separation of the liquid from the more solid parts of fatty matters, employing in preference the *hydro-extractors* used by Seyrig and Co. for drying textile fabrics. Mr. Wilson applies a stout cotton twill in addition to the wire-grating; and in order to avoid the necessity of digging the concrete parts, and to prevent them from clogging the interstices for the discharge of the oily matter, he places the whole in a bag 8 inches in diameter, and of such length that when laid on the rotating machine against the grating the two ends will meet. The speed of the machine must be kept below that at which stearic acid or stearine would pass; which is known by the limpidity of the expressed fluid. To take advantage of the liquefying influence of heat, he keeps the temperature of his own room about 2° F. above that of the substances under treatment.

The chemistry of fat will be found in *Ure's Dictionary of Chemistry*. For *Imports*, &c., see TALLOW.

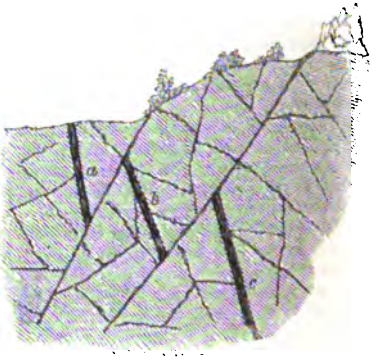
FAULTS (*Failles*, Fr.), in mining, are disturbances of the strata which interrupt the miner's operations, and put him at a loss to discover where the vein of ore or bed of coal has been "*thrown*" by the convulsion of nature.

A mineral vein, may be regarded as a fissure formed by the consolidation of the rocks in which it exists, or by some movement of the entire mass, producing these cracks at right angles to the line of greatest mechanical force; these have been even-

tually filled in with the mineral or metalliferous matter which we find in them. After this has taken place, there has sometimes been a movement of a portion of the ground, and the mineral vein, or lode, has been fractured. A simple illustration of this is the following, *fig.* 736, where we have the mineral vein dislocated, and subsequently to the dislocation there has been a formation of a string of spathose iron, following the bendings of a crack formed by the movement, which, in this case, has been less than the width of the lode. In the large majority of examples the "heave" or "throw" of the lode has been very considerable. It is usual to speak of a *fault* as if the fissure had actually moved the lode. It should be understood that an actual movement of great masses of the solid earth is implied, and consequently, the *lode* having been formed before the movement, it is moved with the rock in which it is enclosed. *Fig.* 738 is the plan of veins 1, 2, 3, 4, and an Elvan course *a a*, which have been dislocated along the line *b*, *c*, and all the lodes and the Elvan course moved. In this case the movement has probably taken place from the North towards the South. This disturbance will be continued to a great depth, and in *fig.* 737 is a section showing the dislocation of a lode into three parts. In

736

737



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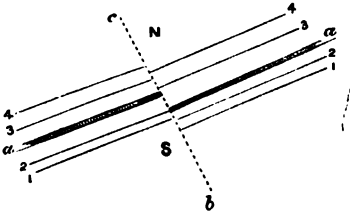

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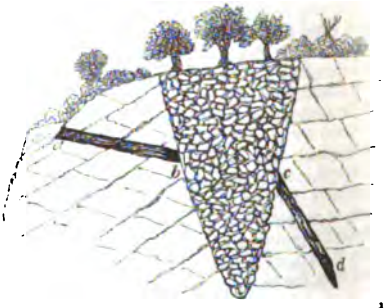


this case the movement has probably been the subsidence of that portion of the ground containing the lode *b*, and the further subsidence of that portion containing the lode *a*; the condition of the surface being subsequently altered by denudation. The inclination of a lode is frequently changed by these movements, thus *fig.* 739 supposes *c d* to represent the original condition of the lode by a convulsion, the portion *a b* has fallen away leaving a chasm between, and the "dip" or inclination of the lode is therefore materially changed. The direction of the lode is frequently altered by these movements. Many lodes in Cornwall have a direction from the N. of E. to the S. of W. up to a fault, on the other side of which the direction is changed from the S. of E. to the N. of W. Where these disturbances are of frequent occurrence, the difficulties of mining are greatly increased.

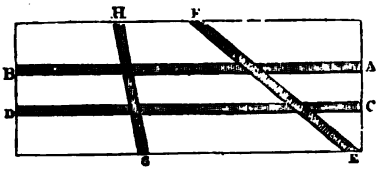
The dislocations and obstructions found in coal-fields, which render the search for coal so difficult, and their mining so laborious and uncertain, are the following:—

1. *Dikes.* 2. *Slips or Faults.* 3. *Hitches.* 4. *Troubles.*

The first three, infer dislocation of the strata; the fourth, changes in the bed of coal itself.

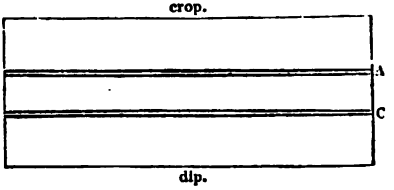
1. A *dike* is a wall of extraneous matter, which divides all the beds in a coal-field. Dikes extend not only in one line of bearing through coal-fields for many miles, but run sometimes in different directions, and have often irregular bendings, but no sharp angular turns. When from a few feet to a few fathoms in thickness, they occur sometimes in numbers within a small area of a coal basin, running in various directions, and even crossing each other. *Fig.* 740, represents a ground plan of a coal-field, intersected wih greenstone dikes. A B and C D are two dikes standing parallel to each other; E F and G H are cross or oblique dikes, which divide both the coal strata and the primary dikes A B and C D.

740



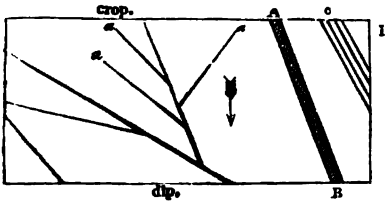
2. *Slips* or *faults* run in straight lines through coal-measures, and at every angle of incidence to each other. *Fig.* 741 represents a ground plan of a coal-field, with two slips A B and C D, the line of bearing of the planes of the strata, which throw them down to the outcrop. This is the simplest form of a slip. *Fig.* 742, exhibits part of a coal-field intersected with slips, like a cracked sheet of ice. Here A B is a dike; while the narrow lines show faults of every kind, producing dislocations varying in amount of slip from a few to a great many fathoms. The faults at the points *a*, *a*, *a* vanish; and the lines at c denote four small partial slips called *hitches*.

741



The effects of slips and dikes on the coal strata appear more prominently when viewed in a vertical section, than in a ground plan, where they seem to be merely walls, veins, or lines of demarcation. *Fig.* 743 is a vertical section of a coal-field,

742



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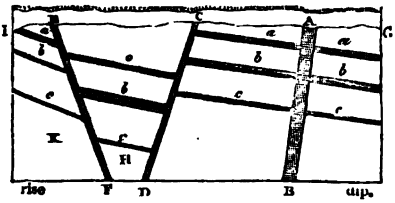
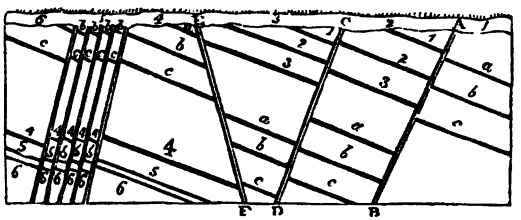


from dip to rise, showing three strata of coal *a*, *b*, *c*. A B represents a dike at right angles to the plane of the coal-beds. This rectangular wall merely separates the coal-measures, affecting their line of rise; but further to the rise, the oblique dike C D interrupts the coals *a*, *b*, *c*, and not only disjoins them, but has produced a movement which has thrown them and their concomitant strata greatly lower down; but still, with this depression, the strata retain their parallelism and general slope. Nearer to the outcrop, another dike, E F, interrupts the coals *a*, *b*, *c*, not merely breaking the continuity of the planes, but throwing them moderately up, so as to produce a steeper inclination, as shown in the figure. It sometimes happens that the coals in the compartment H, betwixt the dikes C and E, may lie nearly horizontal, and the effect of the dike E, F, is then to throw out the coals altogether, leaving no vestige of them in the compartment K.

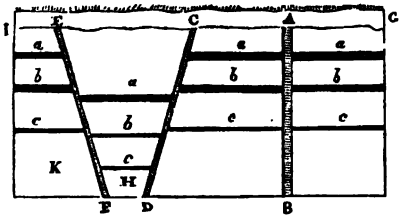
744



The effect of slips on the strata is also represented in the vertical section, *fig.* 744, where *a*, *b*, *c* are coals with their associated strata, A B is an intersecting slip, which throws all the coals of the first compartment much lower, as is observable in the second, No. 2; and from the amount of the slip, it brings in other coal-seams, marked 1, 2, 3, not in the

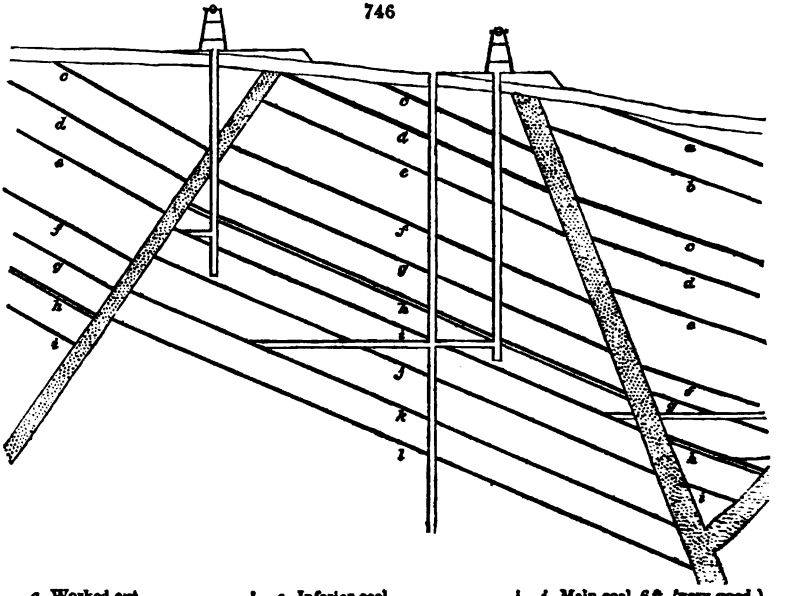
compartment No. 1. C D, is a slip producing a similar result, but not of the same magnitude; E F represents a slip across the strata, reverse in direction to the former; the effect of which is to throw up the coals, as shown in the area No. 4. Such a slip occasionally brings into play seams seated under those marked *a*, *b*, *c*, as seen at 4, 5, 6; and it may happen that the coal marked 4 lies in the prolongation of a well-known seam, as *c*, in the compartment No. 3, when the case becomes puzzling to the miner. In addition to the above varieties, a number of slips or hitches are often seen near one another, as in the area marked No. 5, where the individual displacements are inconsiderable, but the aggregate dislocation may be great, in reference to the seams of the 6th compartment.

745



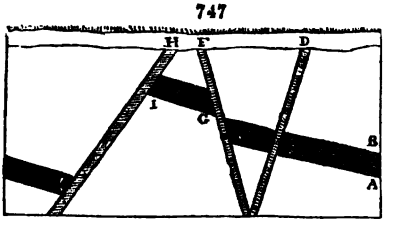
The results of dikes and slips on a horizontal portion of a field are exemplified in *fig.* 745. Where the coal-measures are horizontal, and the faults run at a greater angle than 45° to the line of bearing, they are termed "dip" and "rise" faults, as A B, C D, E F. The following *fig.* 746, which is an accurate section of the Mostyn coal-field, Flintshire, will show the amount to which those disturbances are experienced. The letters mark with sufficient distinctness the beds on either side of the faults.

746



a. Worked out.
b. Ditto.
c. 5 yd. coal worked out.
d. 3 yd. ditto.
e. Inferior coal.
f. Ditto.
g. Yard coal worked out.
h. 4 ft. coal (tolerable).
i. Main coal, 6 ft. (very good.)
j. 5 ft. coal.
k. Stone coal.
l. 3 ft. coal.

747



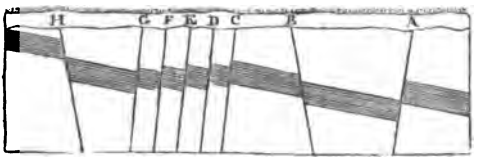
Coal viewers or engineers regard the dislocations now described as being subject in one respect to a general law, which may be thus explained:— Let *fig.* 747 be a portion of a coal-measure; A, being the pavement and B the roof of the coal-seam. If, in pursuing the stratum at C, a dike D occurs, standing at right angles with the pavement, they conclude that the dike is merely a partition-wall between the beds by its own thickness, leaving the coal-seam undisturbed on either side; but if a dike F forms, as at E,

an obtuse angle with the pavement, they conclude that the dike is not a simple partition between the strata, but has thrown up the several seams into the predicament shown at G. Finally, should a dike H make at I an acute angle with the pavement, they conclude that the dike has thrown down the coal measures into the position of K.

Dikes and faults are denominated upthrow or downthrow, according to the position they are met with in working the mine. Thus in *fig.* 743, if the miner is advancing to the rise, the dike A B obviously does not change the direction; but C D is a downthrow dike of a certain number of fathoms towards the rise of the basin, and E F is an upthrow dike likewise towards the rise. On the other hand, when the dikes are met with by the miner in working from the rise to the dip, the names of the above dikes would be reversed; for what is an upthrow in the first case, becomes a downthrow in the second, relative to the mining operations.

3. We have seen that *hitches* are small and partial slips, where the dislocation does not exceed the thickness of the coal-seam; and they are correctly enough called *steps* by the miner. *Fig.* 748 represents the operation of the *hitches* A, B, C, D, E, F, G, H, on the coal-measures. Though observed in one or two seams of a field, they may not appear in the rest, as is the case with dikes and faults.

748



In the above description the language of the mine has been retained, but in the case of the dike, as of the *fault-proper*, it is not that the dike has lifted the coal bed up or down, but during the convulsive movements of the earth, when those trap dikes were being forced from below, great movements were produced on either side of the fissures, through which the molten matter ascended, and hence the alteration in the position of the beds, which were previously, perhaps, nearly in a horizontal plane,

FEATHERS. (*Plumes*, Fr.; *Federn*, Germ.) "The most beautiful, the most complex, and the most highly elaborated of all the coverings of animals, due to the development of the epidermal system, is the plumage of birds." — *Owen.*

A feather consists of the "*quill*," the "*shaft*," and the "*vane*." The vane consists of "barbs" and "barbules."

The *quill* is pierced by a lower and an upper orifice, and contains a series of light, dry, conical capsules, fitted one upon another, and united together by a central pedicle.

The *shaft* is slightly bent, the concave side is divided into two surfaces by a middle longitudinal line continued from the upper orifice of the quill, the convex side is smooth. Both sides are covered with a horny material similar to that of the quill, and they enclose a peculiar white, soft, elastic substance, called the "*pith*." The *barbs* are attached to the sides of the shaft. The *barbules* are given off from either side of the barbs, and are sometimes similarly barbed themselves, as may be seen in the barbules of the long feathers of the peacock's tail.

The barbules are commonly short and close set, and curved in contrary directions, so that two adjoining series of barbules interlock together and form the mechanism by which the barbs are compacted into the close and resisting vane of the quill, or "feather," properly so called. When the barbules are long and loose, they characterise that form of the feather which is properly called a "plume," and such are the most valuable products of the plumage of birds in a commercial point of view, as *e. g.* the plumes of the ostrich.

The Down. — The lower barbs in every kind of feather are usually loose, forming the down, which is increased in most birds by what is called the "accessory plume." This is usually a soft downy tuft, but varies in different species, and even in the feathers of different parts of the body of the same bird. The value of feathers for bed stuffing depends upon the proportion of loose soft down that enters into their composition; and as the "accessory plume" in the body feathers of the swans, geese, and ducks, is almost as long as the feather from which it springs, hence arises the commercial value of the feathers of those aquatic birds. — *Owen.*

The first covering of the young bird is a down. In most birds a certain portion of the down feathers is retained with the true feathers, and this proportion is usually greatest in the aquatic birds.

It is most remarkable in the eider duck (*Anas mollissima*). "The down of the eider combines, with its peculiar softness, fineness, and lightness, so great a degree of elasticity that the quantity of this beautiful material which might be compressed and concealed between the two hands of a man, will serve to stuff the coverlet of a bed." — *Owen.*

Feathers constitute the subject of the manufacture of the *Plumassier*, a name given to the artisan who prepares the feathers of certain birds as ornaments for ladies and for military men, and to him also who combines the feathers in various forms. We shall content ourselves with describing the method of preparing ostrich feathers, as most others are prepared in the same way.

Several qualities are distinguished in the feathers of the ostrich; those of the male, in particular, are whiter and more beautiful. Those upon the back and above the wings are preferred; next those of the wings, and lastly, of the tail. The down is merely the feathers of the other parts of the body, which vary in length from 4 to 14 inches. This down is black in the males, and grey in the females. The finest white feathers of the female have always their ends a little greyish, which lessens their lustre, and lowers their price. These feathers are imported from Algiers, Tunis, Alexandria, Madagascar, and Senegal; this being the order of their value.

The *scouring process* is thus performed:—4 ounces of white soap, cut small, are dissolved in 4 pounds of water, moderately hot, in a large basin; and the solution is made into a lather by beating with rods. Two bundles of the feathers, tied with packthread, are then introduced, and are rubbed well with the hands for five or six minutes. After this soaping they are washed in clear water, as hot as the hand can bear.

The whitening or bleaching is performed by three successive operations.

1. They are immersed in hot water mixed with Spanish white, and well agitated in it; after which they are washed in three waters in succession.

2. The feathers are azured in cold water containing a little indigo tied up in a fine cloth. They should be passed quickly through this bath.

3. They are sulphured in the same way as straw hats are (see SULPHURING); they are then dried by hanging upon cords, when they must be well shaken from time to time to open the fibres.

The ribs are scraped with a bit of glass cut circularly, in order to render them very pliant. By drawing the edge of a blunt knife over the filaments they assume the curly form so much admired.

Those feathers which are of a dingy colour are dyed black. For 20 pounds of feathers, a strong decoction is made of 25 pounds of logwood in a proper quantity of water. After boiling it for 6 hours, the logwood is taken out, 3 pounds of copperas are thrown in; and, after continuing the ebullition for 15 or 20 minutes, the copper is taken from the fire. The feathers are then immersed by handfuls, thoroughly soaked, and worked about; and left in two or three days. They are next cleansed in a very weak alkaline lye, and soaped three several times. When they feel very soft to the touch, they must be rinsed in cold water, and afterwards dried. White feathers are very difficult to dye a fine black.

For dyeing other colours, the feathers should be previously well bleached by the action of the sun and the dew; the end of the tube being cut sharp like a toothpick, and the feathers being planted singly in the grass. After fifteen days' exposure, they are cleared with soap as above described.

Rose colour or *pink*, is given by safflower and lemon juice.

Deep red, by a boiling hot bath of Brazil wood, after aluming.

Crimson. The above deep red feathers are passed through a bath of cudbear.

Prune de Monsieur. The deep red is passed through an alkaline bath.

Blues of every shade, are dyed with the indigo vat.

Yellow; after aluming, with a bath of turmeric or weld.

Other tints may be obtained by a mixture of the above dyes.

Feathers supply us with a soft elastic down on which we can repose our wearied frames, and enjoy sweet slumbers. Such are called *bed* feathers.

Goose feathers are most esteemed. There is a prejudice that they are best when plucked from the living bird, which is done thrice a year, in spring, midsummer, and the beginning of harvest. The qualities sought for in bed feathers are softness, elasticity, lightness, and warmth. Their only preparation when cleanly gathered are a slight beating to clear away the loose matter, but for this purpose they must be first well dried either by the sun or stove. Stoving or hot air being also necessary to remove any animal matter liable to putrefy.

The feathers of the eider duck, *Anas mollissima*, called eider down, possess in a superior degree all the good qualities of goose down. It is used only as a covering to beds, and never should be slept upon, as it thereby loses its elasticity.

Quills for writing. These consist usually of the feathers plucked out of the wings of geese. Dutch quills have been highly esteemed, as the Dutch were the first who hit upon the art of preparing them well, by clearing them both inside and outside from a fatty humour with which they are naturally impregnated, and which prevents the ink from flowing freely along the pens made with them. The Dutch for a long time

employed hot cinders or ashes to attain this end; and their secret was preserved very carefully, but it at length transpired, and the process was then improved. A bath of very fine sand must be kept constantly at a suitable temperature, which is about 140° F.; into this the quill end of the feather must be plunged, and left in it a few instants. On taking the feathers out they must be strongly rubbed with a piece of flannel, after which they are found to be white and transparent. Both carbonate of potash in solution and dilute sulphuric acid have been tried to effect the same end, but without success. The yellow tint which gives quills the air of age, is produced by dipping them for a short time in dilute muriatic acid, and then making them perfectly dry. But this process must be preceded by the sand-bath operation.

Quills are dressed by the London dealers in two ways; by the one, they remain of their natural colour; by the other, they acquire a yellow tint. The former is called the Dutch method, and the principal workman is called a Dutcher. He sits before a small stove fire, into which he thrusts the barrel of the quill for about a second, then lays its root quickly below his blunt-edged knife, called a hook, and, pressing this firmly with the left hand, draws the quill briskly through with his right. The bed on which the quill is laid to receive this pressure is called the plate. A skilful workman can pass 2000 quills through his hands in a day of ten hours. They are next cleansed by being scrubbed by a woman with a piece of rough dog-fish skin, and then tied up in bundles.

In the goose's wing, the five exterior feathers only are valuable for writing; the first is the hardest and roundest of all, but the shortest; the next two are the best of the five. The heaviest quills are generally the best.

FECULA (*Fecule*, Fr.; *Stärkemehl*, Germ.) sometimes signifies corn flour, sometimes starch, from whatever source obtained; and it is also applied to chlorophyll, the green matter of plants. The term is applied to any pulverulent matter obtained from plants by simply breaking down the texture, washing with water, and subsidence.

FEEDER, *a mining term*. A small lateral lode falling into the main lode or mineral vein.

FELL. The hide of an animal.

FELL-MONGER. The business of the fellmonger is to separate the wool from the skin. The wool is sold to the woolstapler, and the stripped skins sent to the leather dressers or parchment makers.

FELSPAR (*Orthose*, Fr.; *Feldspath*, Germ.) is a mineral crystallising in oblique rhomboidal prisms, susceptible of two cleavages; lustre more pearly than vitreous; spec. grav. 2·39 to 2·58; scratches glass, but is softer than quartz; yields no water when calcined; fusible at the blowpipe into a white enamel; not affected by acids. The liquid left from its analytical treatment with nitrate of baryta, nitric acid, and carbonate of ammonia affords on evaporation an alkaline residuum which precipitates platina from its chloride, and appears from this, as well as other tests, to be potash. Felspar consists of silica, 66·75; alumina, 17·50; potash, 12; lime, 1·25; oxide of iron, 0·75. — (*Rose.*) This mineral is a leading constituent of granite; some varieties of which, by the decomposition of the included felspar, furnish the petuntze or Cornish stone, so much used in the porcelain and best pottery manufactures.

The Felspars may be divided into four groups:—

I. Potash felspar (which often contains some soda); *common felspar*, or *orthoclase*; and *leucite*.

II. Soda felspar (or soda and potash); *albite*, *ryacolite*, *oligoclase*, and *nepheline*.

III. Soda and lime felspar (containing some potash), *andesine*, *vosgite*.

IV. Lime felspar; *anorthite*, *labradorite*, *thiorsaurite*.

V. Lithia felspar, or *petalite*.

I. ORTHOCLASE, the common constituent of granite, of which it ordinarily composes from 40 to 45 per cent., consists of silica, 65·85, alumina, 18·06, potash, 16·59 = 100·00. It is colourless, or pale flesh-coloured, or yellow. The name is generally restricted to the subtranslucent varieties, there being many sub-varieties founded on variations of lustre, colour, &c., to which other names have been given. Amongst the varieties so comprehended under the general name of orthoclase, the principal are adularia, transparent or translucent felspars found in large crystals in granitic rocks. Moonstone and sunstone are varieties of adularia, which are described under their proper letters. In addition to potash, some specimens of adularia contain more than four per cent. of soda.

GLASSY FELSPAR (*Sanidin*, *ice-spar* in part), occurs crystallised in the form of a clear transparent glass in trachytic and volcanic rocks.

MURCHISONITE, named after the distinguished geologist and founder of the Silurian system, is a yellowish-grey or flesh-red felspar from Dawlish, and from Heavitree, near Exeter. It is remarkable for its opalescence.

ERYTHRITE is a flesh-coloured felspar, occurring in amygdaloid near Kilpatrick. It contains 3 per cent. of magnesia.

LEUCITE is not so hard as orthoclase, is transparent and infusible. It occurs in detached trapezohedral crystals of a white colour, which, from the similarity of their forms to the common variety of garnet, have obtained the name of "white garnet." It is found abundantly in trachyte on the Rhine, between Lake Laach and Andernach, and also in the older lavas of Vesuvius, some of which appear to be almost entirely composed of it. "The leucitic lavas, of the neighbourhood of Rome, have been used, for the last 2000 years at least, in the formation of millstones."—*Dana.*

It is composed of silica, 55·1; alumina, 23·4; potash, 21·5 = 100·0.

II. ALBITE, or *Cleavelandite* is frequently a constituent of granite, and, more frequently than common felspar, of syenite and greenstone; but it often occurs associated with the latter in the same granite, when it may be distinguished by its greater whiteness and translucency. It is composed of silica, 68·7; alumina, 19·5; soda, 11·8 = 100·0.

RYACOLITE is supposed by Rose to be a mixture of felspar and nepheline. It resembles glassy felspar, and occurs in doubly oblique rhombic prisms. It consists of silica, 51·86; alumina, 28·66; lime, 1·30; soda, 11·60; potash, 6·58 = 100·00.

It is found in the trachytes of Bohemia and Hungary, in the lavas of Vesuvius, and in pitchstone in the islands of Arran and Rum.

OLIGOCLASE, or *soda spodumene*, consists of silica, 62·3; alumina, 23·5; soda, 14·2 = 100·0. It occurs in porphyry, granite, syenite, serpentine, and basalt. At Teneriffe it is met with in trachyte.

NEPHELINE, or *Rhomboidal felspar*, occurs in six-sided prisms, and is composed of silica, 44·4; alumina, 33·6; soda, 16·9; potash, 5·1 = 100·0.

The name nepheline includes the crystallised varieties from Vesuvius, while, under the name Elæolite, are comprised the coarser massive varieties with a greasy lustre. It is found in the older lavas of Vesuvius, and in the lava of Capo di Bove, near Rome.

III. ANDESINE occurs in a whitish syenite in the Andes, in the Vosges, and elsewhere. It consists of silica, 60·16; alumina, 23·86; peroxide of iron, 1·65; magnesia, 0·84; lime, 5·91; soda, 6·58; potash, 1·00; = 100·00.

Vosgite is Labradorite rendered hydrous by partial alteration. It is of a whitish colour, sometimes with a shade of green or blue, and has a pearly or greasy lustre. It consists of silica, 49·32; alumina, 30·07; peroxide of iron, 0·70; protoxide of manganese, 0·60; lime, 4·25; magnesia, 1·96; soda, 4·85; potash, 4·45; water, 3·15 = 99·35.—(*Delesse.*) Found in the porphyry of Ternuay in the Vosges.

IV. ANORTHITE occurs in white translucent or transparent crystals, with a vitreous lustre, inclining to pearly on the planes of cleavage. It consists of silica, 43·2; alumina, 36·8; lime, 20·0. Occurs among the old lavas of Vesuvius in the ravines of Monte Somma, and in the island of Procida, in the bay of Naples. It has also lately been found by Professor Haughton, in syenitic dykes traversing limestone (forming 85 per cent. of the rock), near Carlingford in Ireland.

THIORSAURITE is an Icelandic variety of anorthite, and consists of silica, 48·36; alumina, 30·59; peroxide of iron, 1·37; magnesia, 0·97; protoxide of manganese, a trace; lime, 17·16; soda, 1·13; potash, 0·62 = 100·20.—*Genth.*

LABRADORITE, or *Labrador felspar*, consists of silica, 53·69; alumina, 29·68; lime, 12·13; soda, 4·50 = 100·00.

It occurs principally as a constituent of other rocks, in the lavas of Etna and Vesuvius, in the oriental verde antique of Greece and other porphyries, as well as in certain hornblendic rocks, granites, and syenites. On the coast of Labrador, whence it was originally brought, it is associated with hornblende, hypersthene, and magnetic iron ore. Labradorite receives a fine polish, and on account of its beautiful chatoyant reflections, it is valued for ornamental purposes and sometimes used in jewellery. The parts exhibiting the varied play of colours are disposed in irregular spots and patches, and the same spot, if held in different positions, displays various tints, of which violet and red are the most rare.

The play of colours is supposed to be produced by microscopic crystals of quartz imbedded in the stone. (?)

It is manufactured into brooches, bracelets, snuff-boxes, &c. It looks best when cut in plain, very flat cabochon, and a great deal of skill is required to divide the stone in such a manner that the iridescent portions (on which its beauty depends) may be displayed to the utmost advantage.

V. PETALITE is remarkable as being the mineral in which Arfvedson first discovered *lithia*. It is white, frequently with a reddish tinge, and possesses a glistening lustre and a lamellar structure. Translucent. Not affected by acids. Emits a blue phosphorescent light when gently heated.

It consists of silica, 77·9; alumina, 17·7; lithia, 3·1; soda, 1·3 = 100·0. The only

known European locality is the iron mine of Utön, an island 35 miles S.E. of Stockholm. It is found in the United States, and in Upper Canada, near York, on Lake Ontario.

FELSPATHIC. Of or belonging to felspar.

FELTING (*Feutrage*, Fr.; *Filzen*, Germ.) is the process by which loose flocks of wool, and hairs of various animals, as the beaver, rabbit, hare, &c., are mutually interlaced into a compact textile fabric. The first step towards making felt is to mix, in the proper proportions, the different kinds of fibres intended to form the stuff; and then, by the vibratory strokes of the bowstring, to toss them up in the air, and to cause them to fall as irregularly as possible, upon the table, opened, spread, and scattered. The workman covers this layer of loose flocks with a piece of thick blanket stuff slightly moistened; he presses it with his hands, moving the hairs backwards and forwards in all directions. Thus the different fibres get interlaced, by their ends pursuing ever tortuous paths; their vermicular motion being always, however, root foremost. As the matting gets denser, the hand pressure should be increased in order to overcome the increasing resistance to the decussation.

A first thin sheet of soft spongy felt being now formed, a second is condensed upon it in like manner, and then a third, till the requisite strength and thickness be obtained. These different pieces are successively brought together, disposed in a way suitable to the wished-for article, and united by continued dextrous pressure. The stuff must be next subjected to the fulling mill. See HAT MANUFACTURE, under which head the process of felting is described.

FERMENT (Eng. and Fr.; *Hefe*, Germ.) is the substance which, when added in a small quantity to vegetable or animal fluids, tends to excite those intestine motions, and changes, which accompany fermentation. It seems to be the result of an alteration which vegetable albumen and gluten undergo with contact of air amidst a fermenting mass. The precipitates or lees which fall down, when fermentation is finished, consist of a mixture of the fermenting principle with the insoluble matters contained in the fermented liquor, some of which, like *hordeine*, existed in the worts, and others are probably generated at the time.

To prepare a pure ferment, or at least a compound rich in that principle, the precipitate separated during the fermentation of a clear infusion of malt, commonly called yeast or barm, is made use of. This pasty matter must be washed in cold distilled water, drained and squeezed between the folds of blotting paper. By this treatment it becomes a pulverulent mass, composed of small transparent grains, yellowish grey when viewed in the compound microscope. It contains much water, and is therefore soft, like moist gluten and albumen. When dried it becomes, like these bodies, translucid, yellowish brown, horny, hard, and brittle. In the soft humid state it is insipid, inodorous, insoluble in water and alcohol. If in this state the *ferment* be left to itself, at a temperature of from 60° to 70° F., but not in too dry a situation, it putrefies with the same phenomena as vegetable gluten and albumen, and leaves, like them, a residuum resembling old cheese. See FERMENTATION and YEAST.

FERMENTATION. (*Fermentation*, Fr.; *Gährung*, Germ.) A change which takes place, under the influences of air and moisture at a certain temperature, in the constituent particles of either vegetable or animal substances. This change is indicated by a sensible internal motion — the development of heat — the evolution of gaseous products. Fermentation may be divided into several kinds, as —

Saccharine,	Butyric,
Acetic,	Glyceric,
Alcoholic or Vinous,	Lactic,
Putrefactive,	Mucous.

Of the latter examples but a brief notice is required. *Mucous fermentation* is established when the juice of the beetroot or carrot is kept at a temperature of 100° for some time, when a tumultuous decomposition takes place. All the sugar disappears, and the liquor is found to contain a large quantity of gum, and of mannite with lactic acid.

Lactic Fermentation. — If a solution of one part of sugar in five parts of water be made to ferment, by the addition of a small quantity of cheese or animal membrane, at a temperature of 90° or 100°, lactic acid is formed, which may be separated by adding a little chalk, the lactate of lime depositing in crystalline grains. In lactic fermentation *mannite* invariably is produced as a secondary product, the formation of which is not explained. It has been suggested that the formation of mannite is connected with the production of succinic acid, which Schmidt, in a letter to Liebig, states that he has found in fermenting liquids containing sugar. He suggests the following formula: —

$$\underbrace{C^6H^8O^6}_{\text{Mannite.}} + \underbrace{C^4H^2O^4}_{\text{Succinic acid.}} = \underbrace{C^{12}H^{12}O^{12}}_{\text{Grape sugar.}}$$

Glyceric Fermentation. — When glycerine is mixed with yeast, and kept in a warm place for some weeks, it is decomposed and converted into *metacetonic acid*. This fermentation resembles the last named. The glycerine, $C^6H^7O^5$, forming metacetonic acid, $C^6H^5O^4$, as sugar, $C^6H^6O^6$, does lactic acid, $C^6H^5O^5$, by loss of the elements of water.—*Kane.*

Butyric Fermentation. — If the lactic fermentation is allowed to proceed beyond the point indicated for the formation of lactate of lime, the precipitate in part redissolves with a very copious evolution of hydrogen gas, and carbonic acid, and the liquor contains butyrate of lime. In this action two atoms of lactic acid, $C^{12}H^{10}O^{10}$, produce butyric acid, $C^8H^7O^3$, carbonic acid, and hydrogen gas.

Putrefactive Fermentation. See PUTREFACTION.

The three first named kinds of fermentation demand a more especial attention from their importance as processes of manufacture. Under the heads respectively—ACETIC ACID, BEER, BREWING, DISTILLATION, MALT, and WINE, will be found everything connected with the practical part of the subject; we have therefore only now to deal with the chemical and physical phenomena which are involved in the remarkable changes which take place. When vegetable substances are in contact with air and moisture, they undergo a peculiar change (*decomposition*). Oxygen is absorbed and carbonic acid and water are given off, while there is a considerable development of heat. This may take place with greater or less rapidity, and thus *eremacausis*, fermentation, or combustion may be the result; the spontaneous ignition of hay (as an example) being the final action of this absorption of oxygen.

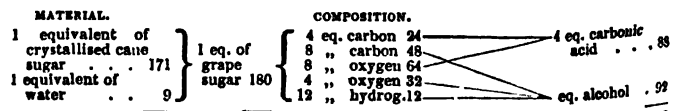
Saccharine Fermentation. — If starch, $C^{12}H^{10}O^{9} + 2HO$, be moistened with an infusion of pale malt, it is rapidly converted into dextrine, $C^{12}H^{10}O^{10}$, and hence into grape sugar, $C^{12}H^{12}O^{12}$; this is especially called the saccharine fermentation, since sugar is the result.

Acetic and Alcoholic Fermentation. — If sugar is dissolved in water, it will remain perfectly unaltered if the air is excluded; but if exposed to the air, a gradual decomposition is brought about, and the solution becomes brown and sour. Oxygen has been absorbed, and *acetic acid* produced. If, however, the sugar is brought into contact with any organic body which is in this state of change, the particles of the sugar participate in the process, carbonic acid is evolved, and *alcohol* produced. There are some substances which are more active than others in producing this change. *Yeast* is the most remarkable; but blood, white of egg, glue, and flesh, if they have begun to putrefy, are capable of exciting fermentation; vegetable albumen and gluten being, however, more active. Vegetable albumen, gluten, and legumin differ from most vegetable bodies in the large quantity of nitrogen which they contain. These substances exist in all fruits, and hence, when fruit is crushed, the sugar of the juices in contact with the albumen or gluten being then exposed to the air, oxygen is rapidly absorbed, the nitrogenous body begins to putrefy, and the sugar passes into fermentative activity. The necessity for oxygen is at the commencement of the decomposition; when the putrefaction of the albumen or gluten has once begun, it extends throughout the mass without requiring any further action of the air. These may be regarded as natural ferments. Yeast is an artificial one. This body will be more particularly described. See YEAST.

To produce a vinous liquid, it is necessary that there shall be present sugar, or some body, as starch or gum capable of conversion into sugar, a certain portion of water, and some ferment—for all practical purposes *yeast*; and the temperature should be steadily maintained at about 80° F. Both cane and grape sugar yield alcohol by fermentation, but Liebig considers that cane sugar, before it undergoes vinous fermentation, is converted into grape sugar by contact with the ferment; and that, consequently, it is grape sugar alone which yields alcohol and carbonic acid.

Grape sugar, as dried at 212°, contains exactly the elements of two atoms of alcohol and four of carbonic acid. As $2(C^4H^6O^2)$ and $4CO^2$ arise from $C^{12}H^{12}O^{12}$.

Cane sugar takes an atom of water to form grape sugar. It follows therefore that cane sugar should in fermenting yield more than its own weight of carbonic acid and alcohol; and it has been ascertained by experiment that 100 parts actually give 104, whilst by theory 105 should be produced, consisting of 51·3 of carbonic acid, and 53·7 of alcohol. — (*Kane.*) Dr. Pereira has given the following very intelligible arrangement to exhibit these changes: —



These facts will sufficiently prove that vinous or alcoholic fermentation is but a metamorphosis of sugar into alcohol and carbonic acid.

Such are the generally received views. We find, however, some other views promulgated which it is important to notice.

Liebig calls *putrefactive fermentation*,—every process of decomposition which, caused by external influences in any part of an organic compound, proceeds through the entire mass without the further co-operation of the original cause. *Fermentation*, according to Liebig's definition, is the decomposition exhibited in the presence of putrefying substances or ferments, by compounds nitrogenous or non-nitrogenous, which alone are not capable of putrefaction. He distinguishes, in both putrefaction and fermentation, processes in which the oxygen of the atmosphere continually co-operates, from such as are accomplished without further access of atmospheric air.

Liebig opposes the view which considers putrefaction and fermentation as the result of vital processes, the development of vegetable formations or of microscopic animals. He adduces that no trace of vegetal formations are perceptible in milk which is left for some time in vessels carefully tied over with blotting paper, not even after fermentation has regularly set in, a large quantity of lactic acid having been formed. He further remarks of fermentative processes, that alcoholic fermentation having been observed too exclusively, the phenomena have been generalised, while the explanation of this process ought to be derived rather from the study of fermentative phenomena of a more general character.

Blondeau propounds the view that every kind of fermentation is caused by the development of fungi. Blondeau states that alcoholic fermentation is due to a fungus which he designates *Torvula cerevisiæ*; whilst another, *Penicillium glaucum*, gives rise to lactic fermentation. The latter fermentation follows the former in a mixture of 30 grm. of sugar, 10 grm. of yeast, and 200 c. c. of water, which has undergone alcoholic fermentation at a temperature of about 20°, being terminated in about two days. Beer yeast, when left in contact with water in a dark and moist place, contains, according to Blondeau, germs both of *Torvula cerevisiæ*, and of *Penicillium glaucum*; the former can be separated by a filter, and will induce alcoholic fermentations in sugar water, whilst the latter are extremely minute, and pass through the filter; the filtrate, mixed with sugar water, gives rise to lactic fermentation. Acetic fermentation is due to the development of *Torvula aceti*; sugar is converted into acetic acid, without evolution of gas, if 500 grm. dissolved in a litre of water, be mixed with 200 grm. of casein, and confined in contact for a month at a temperature of about 20°. The conversion of nitrogenous substances into fat (for instance, of casein, in the manufacture of Roquefort cheese; of fibrin under similar circumstances), which Blondeau designated by the term fatty fermentation (*fermentation adipeuse*), is caused by *Penicillium glaucum* or *Torvula viridis*; and the former fungus is stated to act likewise in butyric and in urea-fermentation (conversion of the urea into a carbonate of ammonia).

Opposed to this view Schubert has published an investigation upon yeast. In order to prove that the action of yeast is due merely to its porosity, he founds his investigation upon some experiments of Brendecke (particularly in reference to the statement that fermentation taking place in a solution of sugar in contact with porous bodies is due to an impurity of sugar); according to which various porous bodies, such as charcoal, paper, flowers of sulphur, &c., to which some bitartrate of ammonia is added, are capable of inducing fermentation in a solution of raw sugar. His observations are also based upon some experiments of his own, which seem to indicate that porous bodies, even without the addition of a salt, are capable of exciting fermentation in a solution of (pure?) cane sugar. Whatever may be the means whereby alcoholic fermentation is induced, he states it to be indispensable that the body in question should be exposed for some time to the influence of air, and that oxygen and carbonic acid are absorbed by the ferment. Both oxygen and carbonic acid, being electro-negative substances, stand in opposition to the electro-positive alcohol, and therefore predispose its formation, but only when they are highly condensed by the powerful surface attraction of the yeast, or of any porous body. The electrical tension, he states, may be increased by many salts, provided that the latter do not at the same time chemically affect either the sugar or the ferment.

C. Schmidt has communicated the results of his experiments to the *Annale Chem. Pharm.* After stating numerous experiments, he continues: "Nor are fungi the *primum movens* of saccharic fermentation; the clear filtrate obtained by throwing almonds crushed in water upon a moist filter, soon induces fermentation in a solution of urea and of grape sugar; in the latter case, no trace of ferment cells can be discovered under the microscope, not even after fermentation is fully developed. If the solution, still containing sugar, is allowed to stand eight days or a fortnight after fermentation has ceased, an exuberant development of cellular aggregations is ob-

served, but no putrefaction ensues; the fungi, well washed and introduced into a fresh solution of grape sugar, continue to grow luxuriantly, inducing, however, if at all, but very weak fermentation, which rapidly ceases; hence the growth of fungi during fermentative processes is but a secondary phenomenon. The increase of the residuary ferment, which occurs after yeast has been in contact with sugar, arises from a development of ferment cellulose, which probably takes place at the expense of the sugar. If muscle, gelatine, yeast, &c., in a very advanced state of putrid decomposition be introduced into a solution of 1 sugar in 4 water, all phenomena of putrefaction disappear; after a few hours, active fermentation sets in, ferment cells being formed, and the liquid contains alcohol, but no mannite. The inactivity of crushed yeast is due, not to the destruction of the fungi, but to the chemical changes which are induced in yeast during the considerable time necessary for complete comminution. The crushed cells, introduced into sugar water, give rise to the production of lactic acid, without evolution of gas." Schmidt is of opinion that fermentation is a process analogous to the formation of ether. He believes that one of the constituents of yeast, together with the elements of grape sugar, gives rise to the formation of one or several compounds, which are decomposed in *statu nascenti* (like sulpho-vinic acid), splitting into alcohol and carbonic acid.

We believe that the preceding paragraphs fairly represent the views which have been promulgated upon the phenomena of change, which are in many respects analogous to those of combustion and of vitality, presented in the fermentative processes. Much has been done, but there are still some points which demand the careful attention of the chemist.

In a practical point of view, the question which arises from the alteration in the specific gravity of the fluid by fermentation is a very important one, a knowledge of the original gravity of beer being required to fix the drawback allowed upon beer when exported, according to the terms of 10 Vict. c. 5. By this act a drawback is granted of 5*s.* per barrel of thirty-six gallons, upon beer exported, of which "the worts used *before fermentation* were not of less specific gravity than 1·054, and not greater specific gravity than 1·081," and a drawback of 7*s.* 6*d.* per barrel upon beer of which "the worts used *before fermentation* were not of less specific gravity than 1·081." The brewer observes the original gravity of his worts by means of some form of the hydrometer, and preserves a record of his observation. The revenue officer has only the beer, from which he has to infer the original gravity. From the great uncertainty which appeared to attend this question, Professors Graham, Hofmann, and Redwood were employed by the Board of Inland Revenue to discover how the original gravity of the beer mgiht be ascertained most accurately from the properties of the beer itself. When worts are fermented, the sugar passes into alcohol, and they lose in density, and assume as beer a different specific gravity The gravity of the wort is called the *original gravity* — that of the beer, *beer gravity*. The report of Graham, Hofmann, and Redwood, upon "original gravities," may be supposed to be in the hands of every brewer; but as some of the points examined materially explain many of the phenomena of vinous fermentation, we have transferred a few paragraphs to our pages: —

"As the alcohol of the beer is derived from the decomposition of saccharine matter only, and represents approximately double its weight of starch sugar, a speculative original gravity might be obtained by simply increasing the extract gravity of the beer by that of the quantity of starch sugar known to be decomposed in the fermentation. The inquiry would then reduce itself to the best means of ascertaining the two experimental data, namely, the extract gravity and the proportion of alcohol in the beer, particularly of the latter. It would be required to decide whether the alcohol should be determined from the gravity of the spirits distilled from the beer; by the increased gravity of the beer when its alcohol is evaporated off; by the boiling point of the beer, which is lower the larger the proportion of alcohol present; or by the refracting power of the beer upon light — various methods recommended for the valuation of the spirits in beer.

"Original gravities so deduced, however, are found to be useless, being in error and always under the truth, to an extent which has not hitherto been at all accounted for. The theory of brewing, upon a close examination of the process, proves to be less simple than is implied in the preceding assumption; and other changes appear to occur in worts, simultaneously with the formation of alcohol, which would require to be allowed for before original gravities could be rightly estimated. It was found necessary to study the gravity in solution of each by itself, of the principal chemical substances which are found in fermented liquids. These individual gravities defined the possible range of variation in original gravity, and they brought out clearly for the first time the nature of the agencies which chiefly affect the result.

"The use of cane sugar is now permitted in breweries, and the solution of sugar

may be studied first as the wort of simplest composition. The tables of the specific gravity of sugar solutions, constructed by Mr. Bate, have been verified, and are considered entirely trustworthy. The numbers in the first and third columns of Table I., which follows, are however, from new observations. It is to be remarked that these numbers have all reference to weights, and not to measures. A solution of cane sugar, which contains 25 grains of sugar in 1000 grains of the fluid, has a specific gravity of 1010·1, referred to the gravity of pure water taken as 1000; a solution of 50 grains of cane sugar in 1000 grains of the fluid, a specific gravity of 1020·2, and so on. The proportion of carbon contained in the sugar is expressed in the second column; the numbers being obtained from the calculation that 171 parts by weight of cane sugar ($C^{12}H^{11}O^{11}$) consist of 72 parts of carbon, 11 parts of hydrogen, and 88 parts of oxygen; or of 72 parts of carbon combined with 99 parts of the elements of water. It is useful to keep thus in view the proportion of carbon in sugar solutions, as that element is not involved in several of the changes which precede or accompany the principal change which sugar undergoes during fermentation, and which changes only affect the proportion of the oxygen and hydrogen, or elements of water, combined with the carbon. The proportion of oxygen and hydrogen in the altered sugar increases or diminishes during the changes referred to; but the carbon remains constant, and affords, therefore, a fixed term in the comparison of different solutions.

TABLE I. — *Specific gravity of solutions of Cane-sugar in water.*

Cane Sugar, in 1000 parts by weight.	Carbon in 1000 parts by weight.	Specific Gravity.
25	10·53	1010·1
50	21·05	1020·2
75	31·58	1030·2
100	42·10	1040·6
125	52·63	1051
150	63·16	1061·8
175	73·68	1072·9
200	84·21	1083·8
225	94·73	1095·2
250	105·26	1106·7

"When yeast is added to the solution of cane sugar in water, or to any other saccharine solution, and fermentation commenced, the specific gravity is observed to fall, owing to the escape of carbonic acid gas, and the formation of alcohol, which is specifically lighter than water; 171 grains of sugar, together with 9 grains of water, being converted into 92 grains of alcohol and 88 grains of carbonic acid ($C^{12}H^{11}O^{11} + HO = 2C^4H^6O^2 + 4CO^2$). But if the process of fermentation be closely watched, the fall of gravity in cane sugar will be found to be preceded by a decided increase of gravity. Solutions were observed to rise from 1055 to 1058, or 3 degrees of gravity, within an hour after the addition of the yeast, the last being in the usual proportion for fermentation. When the yeast was mixed in minute quantity only, such as $\frac{1}{300}$ of the weight of the sugar, the gravity of the sugar solution rose gradually in four days from 1055 to 1057·91, or also nearly 3 degrees; with no appearance, at the same time, of fermentation or of any other change in the solution. This remarkable increase of density is owing to an alteration which takes place in the constitution of the cane sugar, which combines with the elements of water and becomes starch sugar, a change which had been already proved by H. Rose and by Dubrunfaut, to precede the vinous fermentation of cane sugar. The same conversion of cane sugar into starch sugar, with increase of specific gravity, may be shown by means of acids as well as of yeast. A solution of 1000 parts of cane sugar in water, having the specific gravity 1054·64, became with 1 part of crystallised oxalic acid added to it 1054·7; and being afterwards heated for twenty-three hours to a temperature not exceeding 128° Fahr., it was found (when cooled) to have attained a gravity of 1057·63—an increase again of nearly 3° of gravity."

The difference between the gravities of solutions of cane sugar and starch sugar are of great practical value, but these must be studied in the original; the result however being "that the original gravity of a fermented liquid or beer must be different, according as it was derived from a wort of cane sugar or of starch sugar."

The gravity of malt wort was determined to be intermediate between that of pure cane sugar and starch sugar, and solutions containing an equal quantity of carbon exhibited the following gravities: —

Cane sugar - 1072·9 Pale malt - 1074·2 Starch sugar - 1076·0

Two other substances were found to influence the original gravity of the wort: dextrin, or the gum of starch, and caramel. Tables are given of the specific gravities of these, from which the following results have been deduced: —

Starch sugar - - -	1076
Dextrin - - - -	1066·9
Caramel - - - -	1062·3

Caramel is stated to interfere more than dextrin in giving lightness or apparent attenuation to fermented worts, without a corresponding production of alcohol.

"Another constituent of malt wort, which should not be omitted, is the soluble azotised or albuminous principle derived from the grain. The nitrogen was determined in a strong wort of pale malt with hops, of the specific gravity 1088, and containing about 21 per cent. of solid matter. It amounted to 0·217 per cent. of the wort, and may be considered as representing 3·43 per cent. of albumen. In the same wort, after being fully fermented, the nitrogen was found to amount to 0·134 per cent., equivalent to 2·11 per cent. of albumen. The loss observed of nitrogen and albumen may be considered as principally due to the production and growth of yeast, which is an insoluble matter, at the cost of the soluble albuminous matter. Solutions of egg-albumen in water, containing 3·43 and 2·11 per cent. respectively of that substance, were found to have the specific gravities of 1004·2 and 1003·1. Hence a loss of density has occurred during fermentation of 1·1 degree on a wort of 1088 original gravity, which can be referred to a change in the proportion of albuminous matter. It will be observed that the possible influence of this substance and of the greater or less production of yeast during fermentation, upon the gravity of beer, are restricted within narrow limits."

The reporters' proceed: —

"The process required for the determination of the original gravity of beer, must be easy of execution, and occupy little time. It is not proposed, in the examination of a sample, to separate by chemical analysis the several constituents which have been enumerated. In fact, we are practically limited to two experimental observations on the beer, in addition to the determination of its specific gravity.

"One of these is the observation of the amount of solid or extractive matter still remaining after fermentation, which is always more considerable in beer than in the completely fermented wash of spirits. A known measure of the beer might be evaporated to dryness, and the solid residue weighed, but this would be a troublesome operation, and could not indeed be executed with great accuracy. The same object may be attained with even a more serviceable expression for the result, by measuring exactly a certain quantity of the beer, such as four fluid ounces, and boiling it down to somewhat less than half its bulk in an open vessel, such as a glass flask, so as to drive off the whole alcohol. The liquid when cool is made up to four fluid ounces, or the original measure of the beer, and the specific gravity of this liquid is observed. It has already been referred to as to the extract gravity of the beer, and represents a portion of the original gravity. Of a beer of which the history was known, the original gravity of the malt wort was 1121, or 121°; the specific gravity of the beer itself before evaporation, 1043; and the extract gravity of the beer 1056·7, or 56·7°.

"The second observation which can be made with sufficient facility upon the beer, is the determination of the quantity of alcohol contained in it. This information may be obtained most directly by submitting a known measure of the beer to distillation, continuing the ebullition till all the alcohol is brought over, and taking care to condense the latter without loss. It is found in practice that four ounce-measures of the beer form a convenient quantity for the purpose. This quantity is accurately measured in a small glass flask, holding 1750 grains of water when filled up to a mark in the neck. The mouth of the small retort containing the beer is adapted to one end of a glass tube-condenser, the other end being bent and drawn out for the purpose of delivering the condensed liquid into the small flask previously used for measuring the beer. The spirituous distillate should then be made up with pure water to the original bulk of the beer, and the specific gravity of the last liquid be observed by the weighing bottle, or by a delicate hydrometer, at the temperature of 60° Fahr. The lower the gravity the larger will be the proportion of alcohol, the exact amount of which may be learned by reference to the proper tables of the gravity of spirits. The spirit gravity of the beer already referred to proved to be 985·25; or it was 14·05° of gravity less than 1000, or water. The 'spirit indication' of the beer was therefore 14·05°; and the extract gravity of the same beer 56·7°.

"The spirit indication and extract gravity of any beer being given, do we possess data sufficient to enable us to determine with certainty the original gravity? It has already been made evident that these data do not supply all the factors necessary for reaching the required number by calculation.

"The formation of the extractive matter, which chiefly disturbs the original gravity, increases with the progress of the fermentation; that is, with the proportion of alcohol in the fermenting liquor. But we cannot predicate from theory any relation which the formation of one of these substances should bear to the formation of the other, and are unable, therefore, to say beforehand that because so much sugar has been converted into alcohol in the fermentation, therefore so much sugar has also been converted into the extractive substance. That a uniform, or nearly uniform relation, however, is preserved in the formation of the spirits and extractive substance in beer brewing, appears to be established by the observations which follow. Such an uniformity in the results of the vinous fermentation is an essential condition for the success of any method whatever of determining original gravities, at least within the range of circumstances which affect beer brewing. Otherwise two fermented liquids of this class, which agree in giving both the same spirit indication and the same extractive gravity, may have had different original gravities, and the solution of our problem becomes impossible."

The following table, one of several of equal value, gives the results of a particular fermentation of cane sugar. "Fifteen and a half pounds of refined sugar were dissolved in 10 gallons of water, making 10¾ gallons of solution, of which the specific gravity was 1055·3 at 60°; and after adding three fluid pounds of fresh porter yeast, the specific gravity was 1055·95. The original gravity may be taken as 1055·3 (55·3°).

TABLE II. — *Fermentation of Sugar-Wort of original gravity* 1055·3.

I. Number of Observation.	II. Period of Fermentation.		III. Degrees of Spirit Indication.	IV. Degrees of Extract Gravity.	V. Degrees of Extract Gravity *lost*.
	Days.	Hours.			
1	0	0	0	55·30	0·
2	0	6	1·59	52·12	3·18
3	0	12	2·57	47·82	7·48
4	0	19	3·60	43·62	11·68
5	0	23	4·33	40·13	15·17
6	1	5	5·31	35·50	19·80
7	1	12	6·26	31·39	23·91
8	1	19	7·12	27·63	27·67
9	2	11	8·59	20·26	35·04
10	3	11	9·87	13·40	41·90
11	5	12	10·97	7·60	47·70
12	6	12	11·27	4·15	51·15

"Columns III. and V. respectively exhibit the spirit which has been produced, and the solid matter which has disappeared; the first in the form of the gravity of the spirit, expressed by the number of degrees it is lighter than water, or under 1000, and the second by the fall in gravity of the solution of the solid matter remaining below the original gravity 1055·3. This last value will be spoken of as 'degrees of gravity lost;' it is always obtained by subtracting the extract gravity (column IV.) from the known original gravity. To discover whether the progress of fermentation has the regularity ascribed to it, it was necessary to observe whether the same relation always holds between the columns of 'degrees of spirit indication' and 'degrees of gravity lost.' It was useful, with this view, to find what degrees lost corresponded to whole numbers of degrees of spirit indication. This can be done safely from the preceding table, by interpolation, where the numbers observed follow each other so closely. The corresponding degrees of spirit indication and of gravity lost, as they appear in this experiment upon the fermentation of sugar, are as follows:—

TABLE III. — *Fermentation of Sugar-Wort of original gravity* 1055·3.

Degrees of Spirit Indication.	Degrees of Extract Gravity lost.	Degrees of Spirit Indication.	Degrees of Extract Gravity lost.
1	1·71	7	27·01
2	4·74	8	31·87
3	9·26	9	37·12
4	13·48	10	42·55
5	18·30	11	47·88
6	22·54		

" In two other fermentations of cane sugar, the degrees of gravity lost, found to correspond to the degrees of spirit indication, never differed from the numbers of the preceding experiment, or from one another, more than 0·9° of gravity lost. This is a sufficiently close approximation.

" The following table is of much importance: —

TABLE IV. — STARCH-SUGAR.

Degrees of Spirit Indication, with corresponding degrees of gravity lost.

Besides the degrees of gravity lost corresponding to whole degrees of spirit indication, the degrees of gravity lost corresponding to tenths of a degree of spirit indication are added from calculation.

Degrees of Spirit Indication.	·0	·1	·2	·3	·4	·5	·6	·7	·8	·9
0	—	·2	·3	·5	·7	·9	1·0	1·2	1·4	1·6
1	1·9	2·1	2·4	2·7	3·0	3·3	3·6	3·9	4·2	4·6
2	5·0	5·4	5·8	6·2	6·6	7·0	7·5	8·0	8·5	9·0
3	9·5	9·9	10·3	10·7	11·2	11·6	12·0	12·4	12·8	13·3
4	13·8	14·2	14·6	15·0	15·5	15·9	16·3	16·7	17·2	17·7
5	18·3	18·7	19·1	19·5	19·9	20·3	20·8	21·2	21·7	22·2
6	22·7	23·1	23·5	23·9	24·4	24·7	25·2	25·6	26·1	26·6
7	27·1	27·6	28·1	28·6	29·1	29·6	30·0	30·5	31·0	31·5
8	32·0	32·5	33·0	33·5	34·0	34·5	35·0	35·5	36·0	36·6
9	37·2	37·7	38·2	38·7	39·2	39·7	40·3	40·8	41·3	41·8
10	42·4	42·9	43·4	44·0	44·5	45·0	45·6	46·1	46·6	47·2
11	47·7									

" It is seen from this table that for 5° of spirit indication, the corresponding degrees of gravity lost are 18·3°. For 5·9° of spirit indication, the corresponding degrees of gravity lost are 22·2°.

" This table is capable of a valuable application, for the sake of which it was constructed. By means of it, the unknown original gravity of a fermented liquid or beer from cane sugar may be discovered, provided the spirit indication and extract gravity of the beer are observed. Opposite to the spirit indication of the beer in the table, we find the corresponding degrees of gravity lost, which last, added to the extract gravity of the beer, gives its original gravity.

" Suppose the sugar beer exhibited an extract gravity of 7·9° (1007·9), and spirit indication of 11°. The latter marks, according to the table, 47·7° of gravity lost, which added to the observed extract gravity, 7·9°, gives 55·6° of original gravity for the beer (1055·6)."

Similar tables are constructed for starch sugar, and for various worts with and without hops.

After explaining many points connected with the problem, as it presented itself under varied conditions as it respected the original worts, the Report proceeds: —

" The object is still to obtain the spirit indication of the beer. The specific gravity of the beer is first observed by means of the hydrometer or weighing bottle. The extract gravity of the beer is next observed as in the former method; but the beer for this purpose may be boiled in an open glass flask till the spirits are gone, as the new process does not require the spirits to be collected. The spiritless liquid remaining is then made up to the original volume of the beer as before. By losing its spirits, the beer of course always increases in gravity, and the more so the richer in alcohol the beer has been. The difference between the two gravities is the new spirit indication, and is obtained by subtracting the beer gravity from the extract gravity, which last is always the higher number.

" The data in a particular beer were as follows: —

Extract gravity - - - -	1044·7
Beer gravity - - - - -	1035 1
Spirit indication - - - - -	9·6°

" Now the same beer gave by distillation, or the former method, a spirit indication of 9·9°. The new spirit indication by evaporation is, therefore, less by 0·3° than the old indication by distillation. The means were obtained of comparing the two indications given by the same fermented wort or beer in several hundred cases, by

adopting the practice of boiling the beer in a retort, instead of an open flask or basin, and collecting the alcohol at the same time. The evaporation uniformly indicated a quantity of spirits in the beer nearly the same as was obtained by distillation, but always sensibly less, as in the preceding instance. These experiments being made upon fermented liquids of known original gravity, the relation could always be observed between the new spirit indication and the degrees of specific gravity lost by the beer. Tables of the degrees of spirit indication, with their corresponding degrees of gravity lost, were thus constructed, exactly in the same manner as the tables which precede; and these new tables may be applied in the same way to ascertain the original gravity of any specimen of beer. Having found the degrees of spirit indication of the beer by evaporation, the corresponding degrees of gravity lost are taken from the table, and adding these degrees to the extract gravity of the beer, also observed, the original gravity is found. Thus the spirit indication (by the evaporation method) of the beer lately referred to, was 9·6°, which mark 43° of gravity lost in the new tables. Adding these to 1044·7, the extract gravity of the same beer, 1087·7 is obtained as the original gravity of the beer."

The results of the extensive series of experiments made, were, that the problem could be solved in the two extreme conditions in which they have only to deal with the pure sugars entirely converted into alcohol.

"The real difficulty is with the intermediate condition, which is also the most frequent one, where the solid matter of the beer is partly starch sugar and partly extractive; for no accurate chemical means are known of separating these substances, and so determining the quantity of each in the mixture.

"But a remedy presented itself. The fermentation of the beer was completed by the addition of yeast, and the constituents of the beer were thus reduced to alcohol and extractive only, from which the original gravity, as is seen, can be calculated.

"For this purpose a small but known measure of the beer, such as four fluid ounces, was carefully deprived of spirits by distillation, in a glass retort. To the fluid, when cooled, a charge of fresh yeast, amounting to 150 grains was added, and the mixture kept at 80° for a period of sixteen hours. Care was taken to connect the retort, from the commencement, with a tube condenser, so that the alcoholic vapour which exhaled from the wash during fermentation should not be lost. When the fermentation had entirely ceased, heat was applied to the retort to distil off the alcohol, which was collected in a cooled receiver. About three-fifths of the liquid were distilled over for this purpose; and the volume of the distillate was then made up with water to the original volume of the beer. The specific gravity of the last spirituous liquid was now taken by the weighing bottle. To obtain a correction for the small quantity of alcohol unavoidably introduced by the yeast, a parallel experiment was made with that substance. The same weight of yeast was mixed with water, and distilled in another similar retort. The volume of this second distillate was also made up by water to the beer volume; its specific gravity observed, and deducted from that of the preceding spirituous liquid. This alcohol was added to that obtained in the first distillation of the beer, and the weight of starch sugar corresponding to the whole amount of alcohol was calculated. This was the first result.

"For the solid matter of the beer: the spiritless liquid remaining in the retort was made up with water to the beer volume, and the specific gravity observed. A correction was also required here for the yeast, which is obtained by making up the water and yeast distilled in the second retort, to the original volume of the beer, and deducting the gravity of this fluid from the other. The quantity of starch sugar corresponding to this corrected gravity of the extractive matter was now furnished by the table. This was the second result.

"The two quantities of starch sugar thus obtained were added together. The specific gravity of the solution of the whole amount of starch sugar, as found in the table, represented the original gravity of the beer.

"This method must give an original gravity slightly higher than the truth, owing to the circumstance that the dextrin, albumen, and salts, which are found among the solid matters dissolved in beer, are treated as having the low gravity of extractive matter, and accordingly amplified by about one-sixth, like that substance, in allowing for them ultimately as starch sugar. The error from this source, however, is inconsiderable. It is to be further observed, that the error from imperfect manipulation, of which there is most risk in the process, is leaving a little sugar in the extractive matter from incomplete fermentation. This accident also increases the original gravity deduced. The process has given results which are remarkably uniform, and is valuable in the scientific investigation of the subject, although not of that ready and easy execution which is necessary for ordinary practice, and which recommends the former method."

TABLE V. — To be used in ascertaining Original Gravities by the Distillation Process.

Degrees of Spirit Indication with corresponding degrees of gravity lost in Malt Worts.

Degrees of Spirit Indication.	·0	·1	·2	·3	·4	·5	·6	·7	·8	·9
0	—	·2	·6	·9	1·2	1·5	1·8	2·1	2·4	2·7
1	3·0	3·3	3·7	4·1	4·4	4·8	5·1	5·5	5·9	6·2
2	6·6	7·0	7·4	7·8	8·2	8·6	9·0	9·4	9·8	10·2
3	10·7	11·1	11·5	12·0	12·4	12·9	13·3	13·8	14·2	14·7
4	15·1	15·5	16·0	16·4	16.8	17·3	17·7	18·2	18·6	19·1
5	19·5	19·9	20·4	20 9	21·3	21·8	22·2	22·7	23·1	23·6
6	24·1	24·6	25·0	25·5	26·0	26·4	26·9	27·4	27·8	28·3
7	28·8	29·2	29·7	30·2	30·7	31·2	31·7	32·2	32·7	33·2
8	33·7	34·3	34·8	35 4	35·9	36·5	37·0	37·5	38·0	38·6
9	39·1	39·7	40·2	40·7	41·2	41·7	42·2	42·7	43·2	43·7
10	44·2	44·7	45·1	45·6	46·0	46·5	47·0	47·5	48·0	48·5
11	49·0	49·6	50·1	50·6	51·2	51·7	52·2	52·7	53·3	53·8
12	54·3	54·9	55·4	55·9	56·4	56·9	57·4	57·9	58·4	58·9
13	59·4	60·0	60·5	61·1	61·6	62·2	62·7	63·3	63·8	64·3
14	64·8	65·4	65·9	66·5	67·1	67·6	68·2	68·7	69·3	69·9
15	70·5									

TABLE VI. — To be used in ascertaining Original Gravities by the Evaporation Process

Degrees of Spirit Indication with corresponding degrees of gravity lost in Malt Worts.

Degrees of Spirit Indication.	·0	·1	·2	·3	·4	·5	·6	·7	·8	·9
0	—	·3	·7	1·0	1·4	1·7	2·1	2·4	2·8	3·1
1	3·5	3·8	4·2	4·6	5·0	5·4	5·8	6·2	6·6	7·0
2	7·4	7·8	8·2	8·7	9·1	9·5	9·9	10·3	10·7	11·1
3	11·5	11·9	12·4	12·8	13·2	13·6	14·0	14·4	14·8	15·3
4	15·8	16·2	16·6	17·0	17·4	17·9	18·4	18·8	19·3	19·8
5	20·3	20·7	21·2	21·6	22·1	22·5	23·0	23·4	23·9	24·3
6	24·8	25·2	25·6	26·1	26·6	27·0	27·5	28·0	28·5	29·0
7	29·5	30·0	30·4	30·9	31·3	31·8	32·3	32·8	33·3	33·8
8	34·3	34·9	35·5	36·0	36·6	37·1	37·7	38·3	38·8	39·4
9	40·0	40·5	41·0	41·5	42·0	42·5	43·0	43·5	44·0	44·4
10	44·9	45·4	46·0	46·5	47·1	47·6	48·2	48·7	49·3	49·8
11	50·3	50·9	51·4	51·9	52·5	53·0	53·5	54·0	54·5	55·0
12	55·6	56·2	56·7	57·3	57·8	58·3	58·9	59·4	59·9	60·5
13	61·0	61·6	62·1	62·7	63·2	63·8	64·3	64·9	65·4	66·0
14	66·5	67·0	67·6	68·1	63·7	69·2	69·8	70·4	70·9	71·4
15	72·0									

FERRIC ACID. (FeO^2.) This new compound having been prescribed as a source of supplying oxygen to persons confined in diving-bells and in mines, by M. Payerne, claims notice in a practical work. M. Fremy is the discoverer of this acid, which he obtains in the state of ferrate of potash, by projecting 10 parts of dry nitre in powder upon 5 parts of iron filings, ignited in a crucible; when a reddish mass, containing much ferrate of potash, is formed. The preparation succeeds best when a large crucible, capable of holding about a pint of water, is heated so strongly that the bottom and a couple of inches above it, appear faintly, but distinctly red, in which state the heat is still adequate to effect due deflagration without decomposition. An intimate mixture of about 200 grains of *dried* nitre with about one-half its weight of the finest iron filings, is to be thrown at once upon the side of the crucible. The mixture will soon swell and deflagrate. The crucible being taken from the fire, and the ignited mass being cooled, is to be taken out with an iron spoon, pounded, and immediately put into a bottle, and excluded from the air, from which it would speedily

attract moisture, and be decomposed. It is resolved by the action of water, especially with heat, into oxygen gas, peroxide, and nitrate of iron. This acid has not been obtained in a free state; it appears indeed to be scarcely capable of existing alone, decomposing, as soon as liberated, into oxygen and ferric oxide. — *Graham.*

Mr. J. D. Smith prepares the ferrate of potash by exposing to a full red heat a mixture of finely powdered peroxide of iron with four times its weight of dry nitre. It has an amethyst hue, but so deep as to appear black, except at the edges. Oxygen is rapidly evolved by the action of the sulphuric or nitric acid upon its solution. He considers the atom of iron to exist in this compound associated with 3 atoms of oxygen, or double the proportion of that in the red oxide. Hence 52 grains of pure ferric acid should give off 12 grains of oxygen, equal to about 35 cubic inches; but how much of the ferrate of potash may be requisite to produce a like quantity of oxygeu cannot be stated, from the uncertainty of the operation by which it is produced.

FERROCYANIDES. The compounds of the radical ferrocyanogen. The latter radical is bibasic, when, therefore, it combines with hydrogen to form ferrocyanic acid, it takes up two atoms. These two atoms of hydrogen can be replaced by metals as in ferrocyanide of potassium or prussiate of potash, as it is commonly called. See PRUSSIATE OF POTASH. Ferrocyanogen consists of C^6N^3Fe, which may also be written Cy^3Fe, or, for brevity's sake, Cfy.

The modes of preparing the ferrocyanides differ, according as the resulting substance is soluble or insoluble in water. The soluble salts, such as those with alkalies, are prepared either by neutralising hydroferrocyanic acid with the proper metallic oxide, or by boiling prussian blue with the oxide, the metal of which it is intended to combine with the ferrocyangen. Other methods may also be adopted in special cases. The processes for preparing the ferrocyanides of the alkali metals on the large scale will be described in the article PRUSSIATE OF POTASH.

When the ferrocyanide is insoluble in water, it may be prepared by precipitating a salt of the metal with ferrocyanide of potassium. Thus, in the preparation of the reddish or purple ferrocyanide of copper,

$$2(CuO,SO^3) + K^2Cfy = Cu^2Cfy + 2(KO,SO^3).$$

The above equation written in full becomes :—

$$2(CuO,SO^3) + K^2C^6N^3Fe = Cu^2C^6N^3Fe + 2(KO,SO^3).$$

Ferrocyanide of potassium is much used as a test for various metals, in consequence of the characteristic colours of the precipitates formed with many of them. The principal ferrocyanides with their colours and modes of preparation will be found in the following list: —

Ferrocyanide of aluminium.—An instable compound formed by digesting hydrate of alumina with ferroprussic acid.

Ferrocyanides of antimony and arsenic. — Neither of these salts are known in a state of purity.

Ferrocyanide of barium. — This salt may be prepared by boiling prussian blue in slight excess with baryta water and evaporating to crystallisation.

Ferrocyanide of bismuth. — When a solution of ferrocyanide of potassium is added to a solution of a salt of bismuth, a yellow precipitate is obtained. It becomes of a greenish tint on keeping for some time.

Ferrocyanide of cadmium may be attained as a white precipitate on adding a solution of ferrocyanide of potassium to a soluble salt of cadmium.

Ferrocyanide of calcium may be prepared in the same manner as that of barium, but, owing to the sparing solubility of lime in water, we must substitute cream of lime for baryta water.

Ferrocyanide of cerium is a white salt only slightly soluble in water. Its properties are very imperfectly known.

Ferrocyanide of chromium.— The protochloride of chromium gives a yellow precipitate with ferrocyanide of potassium.

Ferrocyanide of cobalt.—Salts of cobalt give a pale blue precipitate with ferrocyanide of potassium. It appears to decompose on keeping, as its colour becomes altered.

Ferrocyanide of copper. — When ferrocyanide of potassium is added to a solution of subchloride of copper, a white precipitate appears, which, on exposure, becomes converted into a purplish red substance, apparently identical with the ordinary ferrocyanide of copper which falls down on the admixture of salts of the protoxide of copper with solutions of ferrocyanide of potassium.

Ferrocyanide of glucinum may be obtained, according to Berzelius, under the form of an amorphous varnish, by decomposing ferrocyanide of lead with a solution of subsulphate of glucina.

Ferrocyanide of hydrogen constitutes ferroprussic acid.

Ferrocyanide of iron, or prussian blue. — This salt exists in several conditions, ac-

cording to the mode of preparation. The ordinary salt is formed by adding a solution of ferrocyanide of potassium to a solution of a persalt of iron. The following equation explains the reaction that ensues with the sesquichloride: —

$$2(Fe^2Cl^3) + 3(CfyK^2 = 3(CfyFe^4) + 6KCl.$$

Ferrocyanide of lead is procured as a white precipitate by adding a solution of ferrocyanide of potassium to a salt of lead.

Ferrocyanide of magnesium is probably best prepared by neutralising ferroprussic acid with magnesia or its carbonate. It forms a pale yellow salt.

Ferrocyanide of manganese may be obtained as a white precipitate, on adding ferrocyanide of potassium to a solution of pure protochloride or protosulphate of manganese.

Ferrocyanide of mercury. — This compound cannot be obtained in a state of purity by precipitation. It has not been sufficiently examined.

Ferrocyanides of molybdenum. — Molybdous salts give, with ferrocyanide of potassium, a dark brown precipitate soluble in excess of the precipitant. If a salt of molybdic oxide be treated in the same manner, a precipitate is obtained, having a similar appearance, but insoluble in excess. Molybdates in solution give precipitates lighter in colour than the last.

Ferrocyanide of nickel is obtained under the form of a pale apple green precipitate, on addition of prussiate of potash to a salt of nickel.

Ferrocyanide of silver. — Ferrocyanide of potassium gives a white precipitate with silver salts.

Ferrocyanide of sodium may be formed by the action of caustic soda on prussian blue.

Ferrocyanide of strontium can be procured precisely in the same manner as the corresponding barium salt substituting solution of caustic strontia (obtained from the nitrate by ignition) for baryta water.

Ferrocyanide of tantalum has probably never been obtained pure. Wollaston found that tantalic acid (dissolved in binoxolate of potash) gave a yellow precipitate with prussiate of potash.

Ferrocyanide of thorium. — A white precipitate is produced by the action of solution of prussiate of potash on salts of thorium.

Ferrocyanide of tin. — Pure salts of tin, whether of the per- or prot-oxide, give white precipitates with ferrocyanide of potassium.

Ferrocyanides of titanium. — Solutions of titanates give a golden brown precipitate when treated with solution of ferrocyanide of potassium.

Ferrocyanides of uranium. — The protochloride gives a pale, and the perchloride a dark reddish brown precipitate with ferrocyanide of potassium.

Ferrocyanide of vanadium. — Salts of vanadic oxide give pale yellow, and of vanadic acid, rich green precipitates with prussiate of potash.

Ferrocyanide of yttrium.—Chloride of yttrium gives a white precipitate with ferrocyanide of potassium.

Ferrocyanide of zinc cannot be prepared by precipitation. It may be obtained in the form of a white powder by the action of oxide or carbonate of zinc on ferroprussic acid. — C. G. W. For FERRO-CYANOGEN, see *Ure's Dictionary of Chemistry.*

FIBRES, or FIBROUS BODIES. From time to time numerous grasses, fibrous barks, and other substances of a similar character, have been introduced into commerce; a few of these only have been found available for manufacture. It is, however, deemed of interest to describe briefly some of these. Some of the more important vegetable fibres will be fully noticed under their respective heads. (See COIR, FLAX, HEMP, &c.)

China Grass. — This fibre is obtained from *Urtica nivea*, which grows abundantly in China, and in various parts of our Indian empire. The samples which have been imported are principally obtained from Canton and Hong-Kong. In 1849, Messrs. Wright and Co. obtained a patent for the preparation of this fibre. Their process consisted essentially of boiling the stems in an alkaline solution, after they had been previously steeped for 24 hours in cold water, and for 24 hours in water at 90° Fahr. The fibre is then thoroughly washed with pure water, and finally subjected to the action of a current of high pressure steam till nearly dry.

Callooee Hemp or Rhea. — This fibre is usually confounded with China grass; but, there is little doubt they are obtained from two different kinds of urtica. The China grass from the *Urtica nivea* of Willdenhow; the Callooee Hemp, *Kahnoi*, or *Rami*, of Sumatra; and the *Rhea* from the *Urtica tenacissima* of Roxburgh. The plant producing the Callooee hemp, was introduced from Bencoolen to Calcutta in 1803, where, under the care of Dr. Roxburgh, it was for many years cultivated in the Botanic Gardens. In 1814, a quantity of the Callooee hemp was imported into England, and properly tested; its practical value was thought so highly of, that the Society of Arts awarded a silver medal to Capt. James Cotton, of the East India Company, who in-

troduced it. "The chief obstacle which interfered, however, with its use, was the difficulty which was found to exist in the preparation of the fibre from the stems of the plants; none of the processes usually adopted with flax or hemp were found to be at all suitable to them; and the rude, wasteful, and imperfect means employed by the natives in preparing the fibre for the manufacture of twine, thread, and fishing nets, by the mere process of scraping, were wholly inapplicable on a large scale, and gave besides only a very inferior result. When macerated or retted in water, it was found that the fibre itself was more easily destroyed than the glutinous matter of the stem. During the last forty years, various attempts have been made to devise a good and cheap process for preparing this fibre, but hitherto without much success; and consequently, till quite recently, the cost of the fibre was such as to preclude its being brought into the market as a substitute for flax. But recent investigations have shown that the *Urtica tenacissima* and the *heterophylla* may be obtained in almost unlimited quantities in various parts of India; and a process which has been lately patented appears, to a very great extent, to have removed the practical difficulties which previously stood in the way of its employment by manufacturers; so that in a few years it is probable that the Callooee hemp will constitute an important addition to the fibrous materials employed in the arts."—*Juror's Report, Great Exhibition*, 1851.

Neilgherry Nettle (*Urtica heterophylla*).—This nettle appears to be remarkable beyond all others for its stinging properties. It is abundant in Mysore, flourishing in Alpine jungles. The Todawars prepare the fibre of this plant by boiling the stems in water, after which they readily separate it from the woody parts and then spin it into a coarse but very strong fibre. The Malays simply steep the stems in water for ten or twelve days, after which they are so much softened that the outer fibrous portion is easily peeled off.

Yercum Nar. — This is the native name of the fibres of the *Calotropis* (*Asclepias*) *gigantea*, a plant which grows wild, abundantly, in various parts of the Bengal and Madras presidencies, and is used by the natives in the manufacture of cord called "*Lamb-dore*," or "*Tondee Coir*."

Aloe fibre, or *Nar*, the produce of the *Agave vivipara*, and other allied species. This is often called the "*Silk grass fibre*."

Pine-apple fibre, sometimes called "*Ananas flax*." This has been prepared in Java, and at Travancore. Many fine specimens have been brought to this country.

Plantain fibre. — In the Government establishments of Ceylon this is extensively employed. Canvass and ropes are made of it. It is obtained from the *Musa textilis*. It is calculated that 8 cwt. per acre of this excellent fibre might be obtained.

Mahant bark. — Employed at St. Vincent's in the manufacture of fishing nets, common cord, and coarse lines for fishing.

New Orleans moss (*Tillandsia usneoides*), a substitute for horse hair as a stuffing material for upholsterers. Sometimes the fibrous husk of the Indian corn is used for the same purpose, but it is more brittle than the moss.

Palm-tree fibre. These fibres are obtained from many varieties of the palm.

Grass fibre. Many of the grasses are now being used in the manufacture of paper, and for other purposes.

The following tables by Dr. Roxburgh and Dr. Wright, afford much information as to the relative strengths of different kinds of fibrous substances. The first table gives experiments made by Dr. Roxburgh in 1804; some of the fibres were, however, probably imperfectly prepared.

Common Name.	Botanical Name.	Breaking Weight.
		lbs.
1. Hemp (English)	*Cannabis sativa*	105
2. Murga (Sanseviera)	*Alectris nervosa*	120
3. Aloe	*Agave Americana?*	110
4. Ejoo	*Saguerus Rumphii*	96
5. Donsha	*Æschynomone cannabina*	88
6. Coir	*Cocos nucifera*	87
7. Hemp (Indian)	*Cannabis sativa*	74
8. Woollet comal	*Abroma Augusta*	74
9. ———?	*Banhinia*	69
10. Sunn	*Crotolaria juncea*	68
11. Bunghi paat	*Corchorus olitorius*	68
12. Ghu nala paat	„ *capsularis*	67
13. ———?	*Hibiscus mainhot*	61
14. Flax (Indian)	*Linum usitatissimum*	39

In 1808, Dr. Roxburgh made another series of experiments, of which the following table gives the result : —

Common Name.	Botanical Name.	Breaking Weight.
		lbs.
1. Bowstring hemp	*Asclepias Sp.*	248
2. Callooee hemp	*Urtica tenacissima*	240
3. ——— ?	*Corchorus capsularis*	164
4. Sunn	*Crotolaria juncea*	160
5. Hemp (Indian)	*Cannabis sativa*	156
6. Doncha	*Æschynomone cannabina*	138
7. ——— ?	*Hibiscus strictus*	128
8. Musta paat	„ *cannabinus*	115
9. Bunghi paat	*Corchorus olitorius*	113
10. Plantain	*Musa*	79

Experiments were made not long since by Dr. Wright on several well known vegetable fibres when made into ropes. The following were the results : —

Common Name.	Botanical Name.	Breaking Weight.
		lbs.
1. Yercum nar	*Calotropis gigantea*	532
2. Janapum	*Crotolaria juncea*	407
3. Cutthalay nar	*Agave Americana*	362
4. Cotton	*Gossypium herbaceum*	346
5. Maroot	*Sanseviera zeylanica*	316
6. Pooley mungu	*Hibiscus cannabinus*	290
7. Coir	*Cocos nucifera*	224

The defect of all these fibres is, as it regards their use in weaving, that they break at the knot, and in all weaving processes the fibres require frequent joining.

Of vegetable substances of the nature and quality of undressed hemp we *imported* in 1857, from

	Cwt.	Computed real value.
Spain	7,250	£ 8,997
Mexico	12,301	14,753
British East Indies	5,498	6,899
Other parts	2,309	2,918
	27,358	£33,567

The peculiarities of these fibres are not specified, but as they are not hemp, flax, tow, or jute, we may fairly infer that many of the fibres named above are included in these importations.

FIBRE, VEGETABLE, called also LIGNINE (*Ligneux*, Fr. ; *Pflanzen-faserstoff*, Germ.) ; is the most abundant and general ingredient of plants, existing in all their parts, the root, the leaves, the stem, the flowers, and the fruit ; amounting in the compact wood to 97 or 98 per cent. It is obtained in a pure state by treating saw-dust successively with hot alcohol, water, dilute muriatic acid, and weak potash lye, which, dissolve, first, the resinous ; second, the extractive and saline matters ; third, the carbonate and phosphate of lime ; and, lastly, any residuary substances. Ligneous fibres, such as saw-dust, powdered barks, straw, hemp, flax, linen, and cotton cloth, are convertible by the action of strong sulphuric acid into a gummy substance analogous to *dextrine*, and a sugar resembling that of the grape.

Much attention has, of late years, been directed to the conversion of vegetable fibre into paper. See PAPER.

FIBRINE (Eng. and Fr. ; *Thierischer Faserstoff*, Germ.) constitutes the principal part of animal muscle ; it exists in the chyle, the blood, and may be regarded as the most abundant constituent of animal bodies. It may be obtained in a pure state by agitating or beating new drawn blood with a bundle of twigs, when it will attach itself to them in long reddish filaments, which may be deprived of colour by working them with the hands under a streamlet of cold water, and afterwards freed from any adhering grease by digestion in alcohol or ether.

Fibrine, thus obtained, is solid, white, flexible, slightly elastic, insipid, inodorous, denser than water, but containing 4 fifths of its weight of it, and without action on

litmus. When dried, it becomes semi-transparent, yellowish, stiff, and brittle : water restores its softness and flexibility. 100 parts of fibrine consist of 53·36 carbon, 19·68 oxygen, 7·02 hydrogen, and 19·31 azote. As the basis of flesh, it is a very nutritious substance, and is essential to the sustenance of carnivorous animals.

FICTILE MANUFACTURE. See POTTERY, &c.

FILE (*Lime*, Fr.; *Feile*, Germ.) is a well known steel instrument, having teeth upon the surface for cutting and abrading metal, ivory, wood, &c.

When the teeth of these instruments are formed by a straight sharp-edged chisel, extending across the surface, they are properly called files ; but when by a sharp-pointed tool, in the form of a triangular pyramid, they are termed rasps. The former are used for all the metals, as well as ivory, bone, horn, and wood ; the latter for wood and horn.

Files are divided into two varieties, from the form of their teeth. When the teeth are a series of sharp edges, raised by the flat chisel, appearing like parallel furrows, either at right angles to the length of the file, or in an oblique direction, they are termed *single cut*. But when these teeth are crossed by a second series of similar teeth, they are said to be *double cut*. The first are fitted for brass and copper, and are found to answer better when the teeth run in an oblique direction. The latter are suited for the harder metals, such as cast and wrought iron and steel. Such teeth present sharp angles to the substance, which penetrate it, while single cut files would slip over the surface of these metals. The double cut file is less fit for filing brass and copper, because its teeth would be very liable to become clogged with the filings.

Files are also called by different names according to their various degrees of fineness. Those of extreme roughness are called rough ; the next to this is the bastard cut ; the third is the second cut ; the fourth, the smooth ; and the finest of all, the dead smooth. The very heavy square files used for heavy smith-work are sometimes a little coarser than the rough ; they are known by the name of rubbers.

Files are also distinguished from their shape, as flat, half-round, three-square, four-square, and round. The first are sometimes of uniform breadth and thickness throughout, and sometimes tapering. The cross section is a parallelogram. The half-round is generally tapering, one side being flat, and the other rounded. The cross section is a segment of a circle varying a little for different purposes, but seldom equal to a semicircle. The three-square generally consist of three equal sides, being equilateral prisms, mostly tapering ; those which are not tapering are used for sharpening the teeth of saws. The four-square has four equal sides, the section being a square. These files are generally thickest in the middle, as is the case with the smith's rubber. In the round file the section is a circle, and the file generally conical

The heavier and coarser kinds of files are made from the inferior marks of blistered steel. Those made from the Russian iron, known by the name of old sable, called from its mark CCND, are excellent. The steel made from the best Swedish iron, called Hoop L or Dannemora, makes the finest Lancashire files for watch and clock makers.

The steel intended for files is more highly converted than for other purposes, to give them proper hardness. It should however be recollected, that if the hardness be not accompanied with a certain degree of tenacity, the teeth of the file break, and do but little service.

Small files are mostly made of cast steel, which would be the best for all others, if it were not for its higher price. It is much harder than the blistered steel, and from having been in the fluid state, is entirely free from those seams and loose parts so common to blistered steel, which is no sounder than as it comes from the iron forge before conversion.

The smith's rubbers are generally forged in the common smith's forge, from the converted bars, which are, for convenience, made square in the iron before they come into this country. The files of lesser size are made from bars or rods, drawn down from the blistered bars, and the cast ingots, and known by the name of tilted steel.

The file-maker's forge consists of large bellows, with coke as fuel. The anvil-block, particularly at Sheffield, is one large mass of mill-stone grit. The anvil is of considerable size, set into and wedged fast into the stone ; and has a projection at one end, with a hole to contain a sharp-edged tool for cutting the files from the rods. It also contains a deep groove for containing dies or bosses, for giving particular forms to the files.

The flat and square files are formed entirely by the hammer. One man holds the hot bar, and strikes with a small hammer. Another stands before the anvil with a two-handed hammer. The latter is generally very heavy, with a broad face for the

large files. They both strike with such truth as to make the surface smooth and flat, without what is called hand-hammering. This arises from their great experience in the same kind of work. The expedition arising from the same cause is not less remarkable.

The half-round files are made in a boss fastened into the groove above mentioned. The steel being drawn out, is laid upon the rounded recess, and hammered till it fills the die.

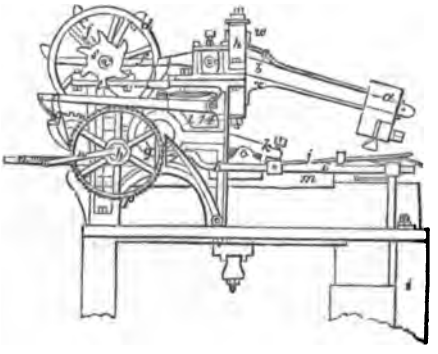
The three-sided files are formed similarly in a boss, the recess of which consists of two sides, with the angle downwards. The steel is first drawn out square, and then placed in a boss with an angle downwards, so that the hammer forms one side, and the boss two. The round files are formed by a swage similar to those used by common smiths, but a little conical.

The file cutter requires an anvil of a size greater or less, proportioned to the size of his files, with a face as even and flat as possible. The hammers weigh from one to five or six pounds. The chisels are a little broader than the file, sharpened to an angle of about 20 degrees. The length is just sufficient for them to be held fast between the finger and thumb, and so strong as not to bend with the strokes of the hammer, the intensity of which may be best conceived by the depth of the impression. The anvil is placed in the face of a strong wooden post, to which a wooden seat is attached, at a small distance below the level of the anvil's face. The file is first laid upon the bare anvil, one end projecting over the front, and the other over the back edge of the same. A leather strap now goes over each end of the file, and passes down upon each side of the block to the workman's feet, which, being put into the strap on each side, like a stirrup, holds the file firmly upon the anvil as it is cut. While the point of the file is cutting, the strap passes over one part of the file only, the point resting upon the anvil, and the tang upon a prop on the other side of the strap. When one side of the file is single cut, a fine file is run slightly over the teeth, to take away the roughness; when they are to be double cut, another set of teeth is cut, crossing the former nearly at right angles. The file is now finished upon one side, and it is evident that the cut side cannot be laid upon the bare anvil to cut the other. A flat piece of an alloy of lead and tin is interposed between the toothed surface and the anvil, while the other side is cut, which completely preserves the side already formed. Similar pieces of lead and tin, with angular and rounded grooves, are used for cutting triangular and half-round files.

Rasps are cut precisely in the same way, by using a triangular punch instead of a flat chisel. The great art in cutting a rasp is to place every new tooth as much as possible opposite to a vacancy.

File cutting machines have been from time to time invented. In 1778 M. de Montigny read a memoir before the Committee of Commerce, in which he mentioned the inventions for file-cutting in 1699 by Duverger, in 1725 by Fardouet, in 1740 by Thiout, in 1756 by Brachat and Gamain, and in 1778; since which, in 1800, Raoul invented a file-cutting machine; and in 1836 Ericsson introduced another. Sir John Robison, just before his death, invented a method for cutting curved files; and in 1843, Messrs. Johnson, Cammell, and Co. received the medal of the Scottish Society of Arts for perfecting Sir J. Robison's scheme. The accompanying wood cuts, which are representations of the file-cutting machine of Mr. W. Shilton of Birmingham, will show the general principle upon which those machines are constructed.

749



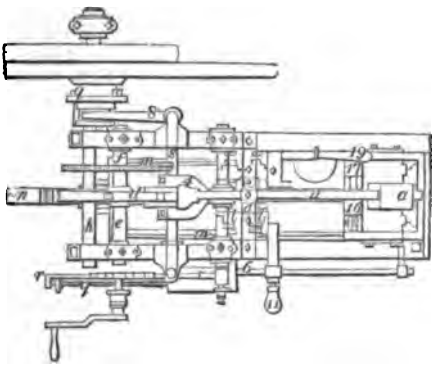
In order to render this invention better understood, two views of the apparatus for producing the cross-cut or teeth of the files, are given.

Fig. 749 is an elevation of the upper part of the file-cutting machine, as seen on one side; *fig.* 750 is a plan or horizontal view, as the machine appears on the top.

a, is the head of the tilt hammer placed in the end of the lever *b*, which is mounted on an axle *c*, turning in proper bearings in the frame work of the machine; *d*, is the tilt wheel mounted on another axle *e*, also turning in bearings on the frame work of the machine, and having any required number of projections or tappets upon it for depressing the tail or shorter end of the hammer or tilt lever *b*.

The tilt wheel *d*, receives its rotatory motion from the toothed wheel *f*, mounted upon the same axle, and it takes into gear with a pinion *g*, upon the main shaft *h*, which is actuated by a band passed from any first mover to the rigger on its end, or in any other convenient manner. The bed upon which the blank piece of steel bears is marked *i*. This bed is firmly supported upon masonry placed upon proper sleepers: *j*, is one of the blank pieces of steel under operation, and is shown secured in the pair of jaws or holding clamps *k*, mounted on centre pins in the slide *l*, *fig.* 750, which slide is held down by a spring and slide beneath, and is moved backwards and forwards in the machine upon the (v) edges *m m*, of the frame, by means of the rack *n* and its pinion; the latter being mounted upon the axle of the ratchet wheel *p*, and which ratchet wheel is made to turn at intervals by means of the pall *q*, upon the end of the lever *r*, *fig.* 750. This lever is depressed, after every cut has been effected upon the blank by means of the teeth or tappets of the wheel *s*, coming in contact with the inclined plane *t*, upon the lever *r*. The tappet wheel *s*, is mounted upon the end of the axle *e*, of the tilt wheel, and consequently revolves with it, and by depressing the lever *r*, every time that a tooth passes the inclined plane *t*, the click *q*, is made to drive the ratchet wheel *p*, and thereby the advancing movement of the blank is effected after each blow of the tilt hammer.

750



There is a strong spring *u*, attached to the upper side of the tilt hammer, its end being confined under an adjustible inclined plane *v*, mounted in the frame *w*, which inclined plane can be raised or lowered by its adjusting screws as required, to produce more or less tension of the spring.

A similar spring is placed on the under side of the tilt hammer, to raise and sustain the cutter or tool clear of the bed after every blow, and in conjunction with safety holders or catchers, to counteract any vibration or tendency the spring *u*, may have to cause the hammer to reiterate the blow.

The end of the lower spring acts on an inclined plane, mounted in the frame *w*, which has an adjusting screw similar to *u*, to regulate the tension of the spring.

In case the under spring should raise, that is, return the hammer, with sufficient force or velocity to cause the top spring *u*, to reiterate the blow, the ends of the safety holders or catchers are made to move under and catch the tail of the lever *b*, immediately on its being raised by the under springs, which is effected by the following means:—The holders are mounted upon a plate or carriage 1, *fig* 749, which turns upon a small pin or axle mounted in the ears of a cross bar; the upper ends of the holders are kept inclined towards the tail of the tilt hammer by means of a spring fixed to the cross bar, and which acts upon one end of the plate or carriage.

In order that the holders may be removed out of the way of the tail of the hammer *b*, when the tilt wheel is about to effect a blow, the tooth of the tilt wheel which last acted upon the hammer comes in contact with an inclined plane fixed on the plate or carriage 1, and by depressing that end of the plate, causes the upper ends of the holders to be withdrawn from under the tail of the hammer *b*. The tilt wheel continuing to revolve, the next tooth advances, and depresses the tail of the hammer, but before it leaves the tail of the hammer, the tooth last in operation will have quitted the inclined plane and allowed the spring to return the holders into their former position. After the tooth has escaped from the tail of *b*, the hammer will immediately descend and effect the blow or cut on the blank, and as the tail of the hammer rises, it will come in contact with the inclined planes at the upper ends of the holders, and force them backwards; and as soon as the tail of the hammer has passed the top of the holders, the spring will immediately force the holders forward under the tail of the hammer, and prevent the hammer rising again until the next tooth of the tilt wheel is about to depress the end of the hammer, when the same movements of the parts will be repeated, and the machine will continue in operation until a sufficient length of the blank of steel (progressively advanced under the hammer) has been operated upon, when it will be thrown out of gear by the following means:—

Upon the sliding bar 6, there is placed an adjustible stop, against which the fore-

most end of the slide *l l*, *fig.* 750, comes in contact as it is moved forward by the rack *n*, and its pinion. The sliding bar 6, is connected at its left end to the bent lever 8, the other end of this lever being formed into a forked arm, which embraces a clutch upon the main shaft, and as the slide *l* continues to advance, it will come in contact with a stop; and when it has brought a sufficient length of the blank pieces of steel under the operation of the cutting tool, the slide *l*, in its progress, will have moved that stop and the bar 6 forward, and that bar, by means of the bent lever 8, will withdraw the clutch on the main shaft, from locking into the boss of the fly-wheel, and consequently stop the further progress of the machine; the rigger and fly-wheel turning loosely upon the main shaft.

The cut file can now be removed from out of the clamps, and reversed to cut the other side, or another blank piece put in its place; and after throwing back the pall *q* of the ratchet wheel *p*, the slide *l*, and with it the fresh blank, may be moved back into the machine by turning the winch handle, on the axle of the ratchet wheel *p*, the reverse way, which will turn the pinion backwards, and draw back the rack *n*, without affecting any other parts of the machine; and on moving back the bar 6, by the handle 11, placed on the stop, the clutches will be thrown into gear again, and the machine proceed to cut the next blank.

When the blanks have been thus cut on one side, and are reversed in the machine to form the teeth upon the other side, there should be a piece of lead placed between the blank and the bed to protect the fresh cut teeth.

It will be seen that the position of the stop upon the bar 6, will determine the length or extent of the blank piece of steel which shall be cut or operated upon; and in order that the progressive movement of the blanks under the cutting tool may be made to suit different degrees of fineness or coarseness of the teeth (that is the distance between the cuts), there is an adjusting screw upon the lever *r*, the head of which screw stops against the under side of an ear projecting from the frame-work, and thereby determines the extent of the motion of the lever *r*, when depressed by the tappets of the wheel *s*, acting upon the inclined plane *t*, consequently determining the number of teeth the ratchet wheel *p* shall be moved round by the pall *q*; and hence the extent of motion communicated by the rack and pinion to the slide *l*, and the blank *j*, which regulates the distance that the teeth of the file are apart, and the lever *r* is forced upwards by a spring pressing against its under side.

It will be perceived that the velocity of the descent of the hammer, and consequently the force of the blow, may be regulated by raising or lowering the inclined plane *v* of the spring *u*; and in order to accommodate the bed upon which the blanks rest to the different inclinations they may be placed at, the part of the bed is formed of a semi-globular piece of hardened steel, which fits loosely into a similar concavity in the bed *r*, and is therefore capable of adjusting itself, so that the blanks shall be properly presented to the cutting tool, and receive the blow or cut in an equal and even manner; or the piece of steel may be of a conical shape, and fit loosely in a similar shaped concavity.

There are guides 16, placed on the top of the bed *i*, for the purpose of keeping the blanks in their proper position towards the cutting tool, and these can be regulated to suit blanks of any width, by turning the right and left handed screw 17. There is also another adjustible stop on the jaws or clamps *k* which serves as a guide when placing the blanks within the jaws: and 19 is a handle or lever for raising the clamps when required, which has a weight suspended from it for the purpose of keeping down the blanks with sufficient pressure upon the bed.

The cutting tool in the face of the hammer, can be placed at any required angle or inclination with the blank, it being secured in the head of the hammer by clamps and screws. In cutting fine files a screw is employed in preference to the rack and pinion, for advancing the slide *l*, and the blank piece of steel in the machine.

Hardening the files. — This is the last and most important part of file making. Whatever may be the quality of the steel, or however excellent the workmanship, if it is not well hardened all the labour is lost.

Three things are strictly to be observed in hardening; first, to prepare the file on the surface, so as to prevent it from being oxidated by the atmosphere when the file is red hot, which effect would not only take off the sharpness of the tooth, but render the whole surface so rough that the file would, in a little time, become clogged with the substance it had to work. Secondly, the heat ought to be very uniformly red throughout, and the water in which it is quenched, fresh and cold, for the purpose of giving it the proper degree of hardness. Lastly, the manner of immersion is of great importance, to prevent the files from warping, which in long thin files is very difficult.

The first object is accomplished by laying a substance upon the file, which when it fuses, forms as it were, a varnish upon the surface, defending the metal from the

action of the oxygen of the air. Formerly the process consisted in first coating the surface of the file with ale grounds, and then covering it over with pulverised common salt (muriate of soda). After this coating became dry, the files were heated red hot, and hardened; after this, the surface was lightly brushed over with the dust of cokes, when it appear white and metallic, as if it had not been heated. This process has lately been improved, at least so far as relates to the economy of the salt, which from the quantity used, and the increased thickness, had become a serious object. Those who used the improved method are now consuming about one fourth the quantity of salt used in the old method. The process consists in dissolving the salt in water to saturation, which is about three pounds to the gallon, and stiffening it with ale grounds, or with the cheapest kind of flour, such as that of beans, to about the consistence of thick cream. The files required to be dipped only into this substance, and immediately heated and hardened. The grounds or the flour are of no other use, than to give the mass consistence, and by that means to allow a larger quantity of salt to be laid upon the surface. In this method, the salt forms immediately a firm coating. As soon as the water is evaporated, the whole of it becomes fused upon the file. In the old method the dry salt was so loosely attached to the file, that the greatest part of it was rubbed off into the fire, and was sublimed up the chimney, without producing any effect,

The carbonaceous matter of the ale grounds is supposed to have some effect in give ing hardness to the file, by combining with the steel, and rendering it more highly carbonated. It will be found, however, upon experiment, that vegetable carbon does not combine with iron, with sufficient facility to produce any effect, in the short space of time a file is heating for the purpose of hardening. Some file makers are in the habit of using the coal of burnt leather, which doubtless produces some effect; but the carbon is generally so ill prepared for the purpose, and the time of its operation so short, as to render the result inconsiderable. Animal carbon, when properly prepared and mixed with the above hardening composition, is capable of giving hardness to the surface even of an iron file.

This carbonaceous matter may be readily obtained from any of the soft parts of animals, or from blood. For this purpose, however, the refuse of shoemakers and curriers is the most convenient. After the volatile parts have been distilled over, from an iron still, a bright shining coal is left behind, which, when reduced to powder, is fit to mix with the salt. Let about equal parts, by bulk, of this powder, and muriate of soda be ground together, and brought to the consistence of cream, by the addition of water. Or mix the powdered carbon with a saturated solution of the salt, till it become of the above consistence. Files which are intended to be very hard, should be covered with this composition, previous to hardening. All files intended to file iron or steel, parlicularly saw files, should be hardened with the aid of this mixture, in preference to that with the flour or grounds. Indeed, it is probable, that the carbonaceous powder might be used by itself, in point of economy, since the ammonia or hartshorn, obtained by distillation, would be of such value as to render the coal of no expense. By means of this method the files made of iron, which in itself, is unsusceptible of hardening, acquired a superficial hardness sufficient for any file whatever. Such files may, at the same time, be bent into any form; and, in consequence, are particularly useful for sculptors and die-sinkers.

The next point to be considered is the best method of heating the file for hardening. For this purpose a fire, similar to the common smith's fire, is generally employed. The file is held in a pair of tongues by the tang, and introduced into the fire, consisting of very small cokes, pushing it more or less into the fire for the purpose of heating it regularly. It must frequently be withdrawn with a view of observing that it is not too hot in any part. When it is uniformly heated, from the tang to the point of a cherry red colour, it is fit to quench in the water. At present an oven, formed of fire-bricks, is used for the larger files, into which the blast of the bellows is directed, being open at one end, for the purpose of introducing the files and the fuel. Near to the top of the oven are placed two cross bars, on which a few files are placed, to be partially heating. In the hardening of heavy files, this contrivance affords a considerable saving, in point of time, while it permits them also to be more uniformly and thoroughly heated.

After the file is properly heated for the purpose of hardening, in order to produce the greatest possible hardness, it should be cooled as soon as possible. The most common method of effecting this is by quenching it in the coldest water. Some file-makers have been in the habit of putting different substances in their water, with a view to increase its hardening property. The addition of sulphuric acid to the water was long held a great secret in the hardening of saw files. After all, however, it will be found, that clear spring water, free from animal and vegetable matter, and as cold as possible, is the best calculated for hardening files of every description.

In quenching the files in water, some caution must be observed. All files, except the half-round, should be immersed perpendicularly, as quickly as possible, so that the upper part shall not cool. This management prevents the file from warping. The half-round file must be quenched in the same steady manner; but, at the same time that it is kept perpendicular to the surface of the water, it must be moved a little horizontally, in the direction of the round side, otherwise it will become crooked backwards.

After the files are hardened, they are brushed over with water, and powdered cokes, when the surface becomes perfectly clean and metallic, They ought also to be washed well in two or three clean waters for the purpose of carrying off all the salt, which, if allowed to remain, will be liable to rust the file. They should moreover be dipped into lime-water, and rapidly dried before the fire, after being oiled with olive oil, containing a little oil of turpentine, while still warm. They are then finished.

FILLIGREE (*Filigrane*, Fr.; *Filigran*, or *Feine Drahtgeflecht*, Germ.) is, as the last term justly expresses it, intertwisted fine wire, used for ornamenting gold and silver trinkets. The wire is seldom drawn round, but generally flat or angular; and soldered by gold or silver solder with borax and the blowpipe. The Italian word, *filigrana*, is compounded of *filum* and *granum*, or granular net-work; because the Italians, who first introduced this style of work, placed small beads upon it.

FILTRATION (Eng. and Fr.; *Filtriren*, Germ.) is a process purely mechanical, for separating a liquid from the undissolved particles floating in it, which liquid may be either the useful part, as in vegetable infusions, or of no use, as the washings of mineral precipitates. The filtering substance may consist of any porous matter in a solid, foliated, or pulverulent form; as porous earthenware, unsized paper, cloth of many kinds, or sand. The white blotting paper sold by the stationers answers extremely well for filters in chemical experiments, provided it be previously washed with dilute muriatic acid, to remove some lime and iron that are generally present in it. Filter papers are first cut square, and then folded twice diagonally into the shape of a cornet, having the angular parts rounded off. Or the piece of paper being cut into a circle, may be folded fan-like from the centre, with the folds placed exteriorly, and turned out sharp by the pressure of the finger and thumb, to keep intervals between the paper and the funnel into which it is fitted, to favour the percolation. The diameter of the funnel should be about three-fourths of its height, measured from the neck to the edge. If it be more divergent, the slope will be too small for the ready efflux of the fluid. A filter covered with the sediment is most conveniently washed by spouting water upon it with a little syringe. A small camel's-hair paint brush is much employed for collecting and turning over the contents in their soft state. Agitation or vibration is of singular efficacy in quickening percolation, as it displaces the particles of the moistened powders, and opens up the pores which had become closed. Instead of a funnel, a cylindrical vessel may be employed, having its perforated bottom covered with a disc of filtering paper folded up at the edges, and made tight there by a wire ring. Linen or calico is used for weak alkaline liquors; and flannels, twilled woollen cloth, or felt-stuff for weak acid ones. These filter bags are often made conical like a fool's cap, and have their mouths supported by a wooden or metallic hoop. Cotton wool put loose into the neck of a funnel answers well for filtering oils upon the small scale. In the large way, oil is filtered in conical woollen bags, or in a cask with many conical tubes in its bottom, filled with tow or cotton wool. Stronger acid and alkaline liquors must be filtered through a layer of pounded glass, quartz, clean sand, or bruised charcoal. The alcarrhazas are a porous biscuit of stone ware made in Spain, which are convenient for filtering water, as also the porous filtering stone of Teneriffe, largely imported into England at one time, but now superseded in a great measure by the artificial filters patented under many forms, consisting essentially of strata of gravel, sand, and charcoal powder.

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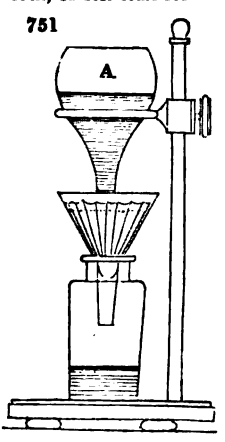

It is convenient to render the filter self-acting, by accommodating the supply of liquid to the rate of percolation, so that the pressure upon the porous surface may be always equally great. Upon the small scale, the lamp-fountain or bird's-glass form so generally used for lamps, will be found to answer.

Fig. 751, represents a glass bottle A, partly filled with the fluid to be filtered, supported in the ring of a chemical stand, and having its mo th inverted into the same liquor in the filter funnel. It is obvious, that whenever this liquor by filtration falls below the lip of the bottle, air

will enter into it, let down a fresh supply to feed the filter, and keep the funnel regularly charged. If larger quantities are to be operated upon, the following apparatus may be employed. *Fig.* 752, A B, is a metallic vessel which may be made air-tight; C is the under pipe provided with a stopcock R, for letting down the liquor into the filter *a b*. The upper pipe *t*, through which the fluid is poured by means of the funnel E, has also a stopcock which opens or shuts, at the same time, the small side tube *u t*, through which, during the entrance of the fluid, the air is let off from the receiver. A glass tube *g*, shows the level of the liquor in the body of the apparatus. In using it, the cock R must be first closed, and the cock S must be opened to fill the receiver. Then the filter is set a going, by re-opening the cock R, so as to keep the fluid in the filter upon a level with the opening of the tube C. Both these pieces of apparatus are essentially the same.

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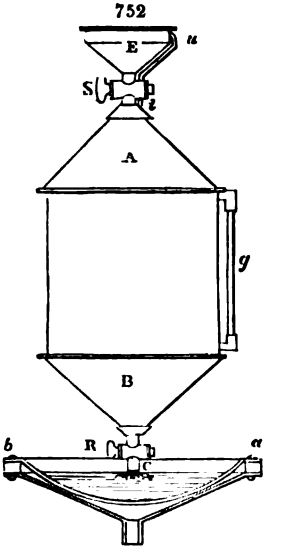

In many manufactures, self-acting filters are fed by the plumber's common contrivance of a ball-cock in which the sinking and rising of the ball, within certain limits, serves to open or shut off the supply of liquor as it may be required or not. Dumont has adopted this expedient for his system of filtering syrup through a stratum of granularly ground animal charcoal or bone-black. *Fig.* 753, is a front view of this apparatus with 4 filters C; and *fig.* 754 is a cross section. The framework B supports the cistern A, in which the syrup is contained. From it the liquor flows through the stop-cock *b*, and the connection-tube *a*, into the common pipe *c*, which communicates, by the short branch tubes *e*, with each of the four filters. The end of the branch tube, which is inside of the filter tub, is provided with a stop-

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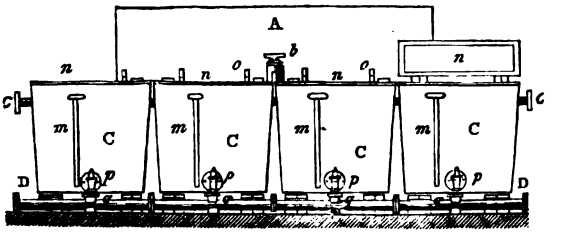

cock *d f*, whose opening, and thereby the efflux of the liquor from the cistern through the tube *a*, is regulated by means of the floating-ball *g*. Upon the brickwork D the filter tub stands, furnished at *h* with a false bottom of zinc or copper pierced with fine holes; besides which, higher up at *i* there is another such plate of metal furnished with a strong handle *k*, by which it may be removed, when the bone-black needs to be changed. In the intervening space *l*, the granular coal is placed. *o* is the cover of the filter tub, with a handle also for lifting it. One portion of it may be raised by a hinge, when it is desired to inspect the progress of the filtration within. *m m* is a slender vertical tube, forming a communication between the bottom part *h*, and the upper portion of the filter, to admit of the easy escape of the air from that space, and from among the bone-black as the syrup descends; otherwise the filtration

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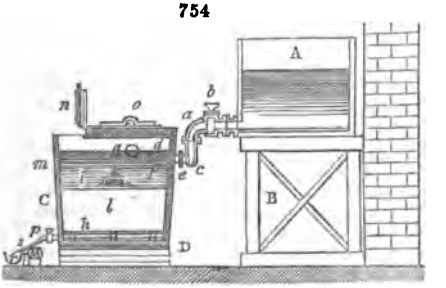

could not go on. *p* is the stopcock through which the fluid collected in the space under *h* is let off from time to time into the common pipe *q*, *fig.* 753. *r* is a trickling channel or groove lying parallel to the tube *q*, and in which, by means of a tube *s*, inserted at pleasure, the syrup is drawn off in case of its flowing in a turbid state, when it must be returned over the surface of the charcoal.

The celerity with which any fluid passes through the filter depends, — 1, upon the porosity of the filtering substance; 2, upon the pressure exercised upon it; and 3, upon the extent of the filtering surface. Fine powders in a liquor somewhat glutinous, or closely compacted, admit of much slower filtration than those which are coarse and free; and the former ought, therefore, to be spread in a thinner stratum and over a more extensive surface than the latter, for equal effect; a principle well exemplified in the working of Dumont's apparatus, just described.

In many cases filtration may be accelerated by the increase of hydrostatic or pneumatic pressure. This happens when we close the top of a filtering cylinder, and connect it by a pipe with a cistern of fluid placed upon a higher level. The pressure of the air may be rendered operative also either by withdrawing it partially from a close vessel, into which the bottom of the filter enters, or by increasing its density over the top of the liquor to be filtered. Either the air pump or steam may be employed to create a partial void in the receiver beneath the filter. In like manner, a forcing pump or steam may be employed to exert pressure upon the surface of the filtering liquor. A common siphon may, on the same principle, be made a good pressure filter, by making its upper leg trumpet-shaped, covering the orifice with filter paper or cloth, and filling the whole with liquor, the lower leg being of such length so as to create considerable pressure by the difference of hydrostatic level. This apparatus is very convenient either on the small or great scale, for filtering off a clear fluid from a light muddy sediment. The pressure of the atmosphere may be elegantly applied to common filters, by the apparatus represented in *fig.* 755, which is merely a funnel enclosed within a gasometer. The case A B bears an annular hollow vessel *a b*, filled with water, in which receiver the cylindrical gasometer, *d*, *e*, *f*, *i*, is immersed. The filter funnel C is secured at its upper edge to the inner surface of the annular vessel *a b*. In consequence of the pressure of the gasometer regulated by the weight *g*, upon the air inclosed within it, the liquid is equally pressed, and the water in the annular space rises to a corresponding height on the outer surface of the gasometer, as shown in the figure. Were the apparatus made of sheet iron, the annular space might be charged with mercury.

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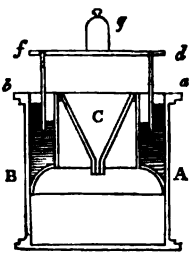

In general, relatively to the application of pressure to filters, it may be remarked, that it cannot be pushed very far, without the chance of deranging the apparatus, or rendering the filtered liquor muddy. The enlargement of the surface is, generally speaking, the safest and most efficacious plan of increasing the rapidity of filtration, especially for liquids of a glutinous nature. This expedient is well illustrated in the creased bag filter now in use in most of the sugar refineries of London. See SUGAR.

In many cases it is convenient so to construct the filtering apparatus, as that the liquid shall not descend, but mount by hydrostatic pressure. This method has two advantages: 1. that without much expensive apparatus, any desired degree of hydrostatic pressure may be given, as also that the liquid may be forced up through several filtering surfaces placed alongside of each other; 2. that the object of filtering, which is to separate the particles floating in the fluid without disturbing the sediment, may be perfectly attained, and thus very foul liquids be cleared without greatly soiling the filtering surface.

Such a construction is peculiarly applicable to the purification of water, either alone, or combined with the downwards plan of filtration. Of the former variety an example is shown in *fig.* 756. The wooden or zinc conical vessel is provided with two perforated bottoms or sieves *e e*, betwixt which the filtering substance is packed. Over this, for the formation of the space *h h*, there is a third shelf, with a hole in its middle, through which the tube *d b* is passed, so as to be water tight. This places the upper open part of the apparatus in communication with the lowest space *a*. From the compartment *h h* a small air tube *l* runs upwards. The filtering substance consists at bottom of pebbles in the middle of gravel, and at the top of fine sand, which may be mixed with coarsely ground bone-black, or covered with a layer of the same. The water to be filtered being poured into the cistern at top, fills through the tube *b d* the inferior compartment *a*, from which the hydrostatic pressure forces the water upward through the perforated shelf, and the filtering materials. The pure water collects in the space *h h*, while the air escapes by the small tube *l*, as the liquid enters. The stopcock *i* serves

to draw off the filtered water. As the motion of the fluid in the filter is slow, the particles suspended in it have time to subside by their own gravity; hence there collects over the upper shelf at *d*, as well as over the under one at *a*, a precipitate or deposit which may be washed out of the latter cavity by means of the stopcock m.

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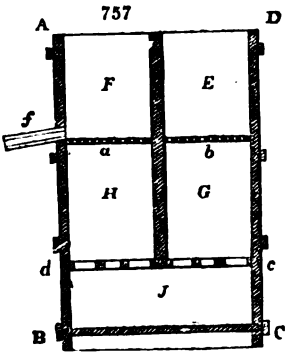

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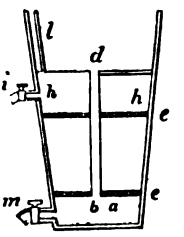

As an example of an upwards and downwards filter, *fig.* 757 may be exhibited. A B C D is a wooden or metallic cistern, furnished with the perforated shelf *c d* near its under part, upon which a vertical partition is fixed through the axis of the vessel. A semicircular perforated shelf is placed at *a*, and a second similar one at *b*. These horizontal shelves rest upon brackets in the sides of the cisterns, so that they may be readily lifted out. The space G is filled with coarse sand, J with moderately fine, and H with very fine. The foul water is poured into the chamber E, and presses through G J H and into the space F, whence it may be drawn by the stopcock *f*.

Fig. 758 represents in section a filtering apparatus consisting of two concentric chambers; the interior being destined for downwards filtration, and the exterior for upwards. Within the larger cistern A, a smaller one B is placed concentrically, with its under part, and is left open from distance to distance, to make a communication between the interior cavity and the exterior annular space. These cavities are filled to the marked height with sand and gravel. The inner cylindrical space has fine sand below, then sharper sand with granular charcoal, next coarse sand, and lastly gravel. The annular space has in like manner fine sand below. The foul water is introduced by the pipe E, the orifice at whose end is acted upon by a ball-cock with

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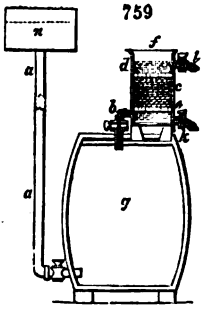


its lever *a*; whereby the water is kept always at the same level in the inner vessel. The water sinks through the sand strata of the middle vessel, passes outwards at its bottom into the annular space, thence up through the sand in it, and collecting above it, is let off by the stopcock on the pipe *b*. When a muddy deposit forms after some time, it may be easily cleared out. The cord *e*, running over the pulleys *f f*, being drawn tight, the ball lever will shut up the valve. The stopcock *d* made fast to the conducting tube E must then be opened, so that the water now overflows into the annular space at A; the tube *c*, in communication with the inner space B, being opened by taking out the stopper *h*. The water thereby percolates through the sand strata in the reverse direction of its usual course, so as to clear away the impurities in the space B, and to discharge them by the pipe *c h*. An apparatus of this kind of moderate size is capable of filtering a great body of water. It should be constructed for that purpose of masonry; but upon a small scale it may be made of stone-ware.

A convenient apparatus for filtering oil upwards is represented in *fig.* 759. *g* is an oil

cask, in which the impure parts of the oil have accumulated over the bottom. Immediately above this, a pipe *a* is let in, which communicates with an elevated water cistern *n*. *f* is the filter (placed on the lid of the cask), furnished with two perforated shelves, one at *e* and another at *d*; which divide the interior of the filter into three compartments. Into the lower space immediately over the shelf *e*, the tube *b*, furnished with a stopcock enters, to establish a communication with the cask; the middle cavity *c* is filled with coarsely ground charcoal or other filtering materials; and the upper one has an eduction pipe *l*. When the stopcocks of the tubes *a* and *b* are opened, the water passes from the cistern into the oil cask, occupies from its density always the lowest place, and presses the oil upwards, without mixing the two liquids; whereby first the upper and purer portion of the oil is forced through the tube *b* into the filter, and thence out through the pipe *l*. When the fouler oil follows, it deposits its impurities in the space under the partition *c*, which may from time to time be drawn off through the stopcock *k*, while the purer oil is pressed upwards through the filter. In this way the different strata of oil in the cask may be filtered off in succession, and kept separate, if found necessary for sale or use, without running any risk of mixing up the muddy matter with what is clear. According to the height of the water cistern *n*, will be the pressure, and of course the filtering force. When the filter gets choked with dirt, it may be easily re-charged with fresh materials.

It has been for many years the custom of the water companies to send the water taken from the river through filter beds, prepared usually of sand and gravel. It was long thought that the effect of these filter beds was merely to separate the solid insoluble matters suspended in the water. It has, however, been shown by the investigations of the late Mr. Henry M. Witt (a chemist of peculiar promise, lost too soon to science, and ere yet the world could recognise his powers), that these filter beds had the power of separating many of the dissolved substances from the water; that, in fact, the soluble salts of lime, and the like, were removed by some peculiar physico-mechanical force, resident, as it appears, as a surface force, in all porous masses. There are many very remarkable examples in nature of the operation of this power in producing beds charged with metalliferous matter, some of which will be described under the head of MINING.

Mr. H. M. Witt communicated to the *Philosophical Magazine* for December, 1856, an account of some experiments on filtration, which are of much value. Many of his experiments were made at the Chelsea Water Works, and they appear of such interest that we quote the author's remarks to some extent.

"The system of purification adopted by the Chelsea Waterworks, at their works at Chelsea, consisted hitherto (for the supply has by this time commenced from Kingston) in pumping the water up out of the river into subsiding reservoirs, where it remained for six hours; it was then allowed to run on to the filter-beds. These are large square beds of sand and gravel, each exposing a filtering surface of about 270 square feet, and the water passes through them at the rate of about 6¼ gallons per square foot of filtering surface per hour, making a total quantity of 1687·5 gallons per hour through each filter.

"The filters are composed of the following strata, in a descending order:—

	ft.	in.
1. Fine sand	2	6
2. Coarser sand	1	0
3. Shells	0	6
4. Fine gravel	0	3
5. Coarse gravel	3	3

These several layers of filtering materials are not placed perfectly flat, but are disposed in waves, and below the convex curve of each undulation is placed a porous earthenware pipe, which conducts the filtered water into the mains for distribution. The depth of water over the sand was 4 feet 6 inches. The upper layer of sand is renewed about every six months, but the body of the filter has been in use for about twenty years.

"Samples of water were taken and submitted to examination:—

"1st, from the reservoir into which the water was at the time being pumped from the middle of the river.

"2nd, from the cistern, after subsidence and filtration."

Experiments were made at different seasons of the year; but one of Mr. Witt's tables will sufficiently show the results.

1. Shows the quantities of the several substances originally present, represented in grains, in the imperial gallon (70,000 grains) of water.
2. The amount present after filtration.
3. The actual quantities separated in grains in the gallon of water.

4. The per centage ratio which the amounts separated bear to the quantities originally present.

	1. Originally present.	2. After filtration.	3. Amount separated.	4. Per centage ratio of separated Matter.
Total solid residue, including suspended matter -	55·60	22·85	32·75	58·90
Organic matter - -	4·05	1·349	2·70	66·66
Total mineral matter -	51·55	21·501	30·049	58·29
Suspended matter - -	28·93	2·285	26·645	92·10
Total dissolved salts -	22·62	19·216	3·404	15·04
Lime - - - - -	8·719	8·426	0·293	3·36

"It has been assumed as a principle that sand filtration can only remove bodies mechanically suspended in water, but I am not aware that this statement has been established by experiment; in fact, I am not acquainted with any published analytical examination of the effects of sand filtration.

"These experiments supply the deficiency, and show, moreover, that these porous media are not only capable of removing suspended matter (80 to 92 per cent.), but even of separating a certain appreciable quantity of the salts from solution in water, viz. from 5 to 15 per cent. of the amount originally present, 9 to 19 per cent. of the common salt, 3 per cent. of the lime, and 5 of the sulphuric acid.

"Taking the purer water from Kingston, two experiments were made simultaneously with the same water, one filtration being through charcoal alone, and the other through sand alone, the sand filter having an area of 4 square feet, and consisting of the following materials: —

	ft.	in.
Fine sand - - - - - - - - -	1	9
Shells - - - - - - - - -		1½
Gravel - - - - - - - - -		1½
Coarse gravel - - - - - - - -		9
	2	9

Results of Sand Filtration.

	Original Water used.	After 23 hours' action.			After 120 hours' action.		
		Comparison.	Amount separated.	Per centage of Quantity separated.	Comparison.	Amount separated.	Per centage ratio of Quantity separated.
Total residue - -	24·578	23·87	0·708	2·88	23·69	0·888	3·613
Mineral salts - - -	23·687	22·858	0·829	3·50	23·04	0 647	2·73
Organic matter - -	0·8906	1·012	- -	- -	0 648	0·2426	
Suspended matter - -	3·509	2·663	0·846	24·109			
Chlorine - - -	0·862	- -	- -	- -	0·671	0·191	22·16
Chloride of Sodium -	1·420	- -	- -	- -	1·105	0·315	22·11
		After 240 hours' action.			After 376 hours' action.		
Total residue - -	24·578	22·534	2·044	8·316	22·507	2·071	8·426
Mineral salts - - -	23·687	21·517	2·170	9·161	21·698	1·989	8·397
Organic matter - -	0·8906	0·917	- -	- -	0·809		
Suspended matter - -	3·509	1·88	1·629	46·423	1·584	1·925	54·85
Chlorine - - -	0·862	0·674	0 188	21·8			
Chloride of Sodium -	1·420	1·110	0 310	21·8			

"Apart from its special interest, as compared with the following experiment, made simultaneously through charcoal, the following points are in themselves remarkable in the results obtained by this filtration through sand: —

"1st. That the filter continued increasing in efficacy even till the conclusion of the experiment, *i. e.*, for 376 hours, not having lost any of its power when the experiment was terminated.

"2nd. That no weighable quantity of dissolved organic matter was removed by the sand in this experiment; but it must be remembered that the quantity originally present was but small.

"3rd. Its power of removing soluble salts was considerable; as a maximum, 21 per cent. of the common salt being separated."

Results of Charcoal Filtration.

	Original Water used.	After 72 hours' action.			After 120 hours' action.		
		Comparison.	Amount separated.	Per centage ratio of Quantity separated.	Comparison.	Amount separated.	Per centage ratio of Quantity separated.
Total residue	24·578	22·13	2·448	9·906	21·644	2·934	11·93
Mineral salts	23·687	21·375	2·312	9·76			
Organic matter	0·8906	0·755	0·1356	15·22			
Suspended matter	3·509	- -	- -	- -	3·06	0·449	12·79
Chlorine	0·862						
Chloride of Sodium	1·420						
		After 240 hours' action.			After 376 hours' action.		
Total residue	24·578	20 821	3·757	15·28	21·374	3·204	13·03
Mineral salts	23·687	- -	- -	- -	20·604	3·083	12·34
Organic matter	0·8906	- -	- -	- -	0·770	0·1206	13·54
Suspended matter	3·509	2·79	0·719	20·48			
Chlorine	0 862						
Chloride of Sodium	1·420						

On comparing this experiment with the preceding, the following point comes out as showing the difference between the effects of sand and charcoal as filtering media.

By the charcoal, speaking generally, a considerably larger quantity of the total residue contained in the water was removed than by the sand, their maximum results being respectively as follows: —

Amount originally present.	Amount separated in Grains in the Gallon.		Amount separated in per centage of the Quantity present.	
	By Sand.	By Charcoal.	By Sand.	By Charcoal.
24·578 grs. in the gallon	2·074	3·757	8·426	15·28

Mr. Way has also shown that agricultural soil possesses the power of separating the soluble salts and organic matter from water in a remarkable manner. There are without doubt many natural phenomena which are immediately dependent upon this power, possessed by porous bodies of all kinds, in a greater or a less degree.

FIRE ANNIHILATORS. This name is given to a portable machine invented by Mr. Phillips, which is adjusted to produce the immediate production of steam, carbonic acid and other gases, which could be at once directed on the burning mass. The machine is cylindrical in form, and slightly conical. For use it is charged with the following composition: charcoal 20 parts, nitrate of potash 60 parts, and gypsum 5 parts. These materials are boiled together in water, and afterwards dried in a stove at the temperature of 100°. The whole is moulded into the form of a brick, down the axis of which penetrates a hollow cavity for the reception of a bottle, which contains a mixture of chlorate of potash and sugar, surmounted by a globule of sulphuric acid. The charge so prepared is placed in a cylindrical vessel, perforated in many places, which is itself within another cylindrical vessel, also perforated for the passage of the gases; both these are contained in a double cylindrical receiver, the lower part of which contains a quantity of water. The apparatus is closed by two covers, in the outer of which is an opening for the escape of the vapour. In the centre of the cover is placed a spike, for the purpose of breaking the glass bottle deposited in the cavity of the charge. The spike being forced down breaks the bottle, and the sulphuric acid causes the instantaneous combustion of the chlorate of potash and sugar, which fires the charge. The gases now escape through the perforations, and heating the air in the water chamber, and causing it to expand, forces the water up a tubular passage into the space between and around the cylindrical vessels placed each within each, and being thus converted into vapour, mixes with the gases, and escapes by the discharge tube, forming a dense cloud, which rapidly extinguishes flame.

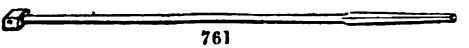
FIRE ARMS, MANUFACTURE OF. This art is divided into two branches, that of the metallic, and that of the wooden work. The first includes the barrel, the lock, and the mounting, with the bayonet and ramrod, for military arms. The second comprises the stock, and in fowling-pieces likewise the ramrod.

The Barrel.—Its interior is called the bore; itsd iameter, the calibre; the back end, the breech; the front end the muzzle; and the closing of the back end, the breech pin or plug. The barrel is generally made of iron. Most military musquets and low-priced guns were formerly fashioned out of a long slip of sheet-iron folded together edge-wise round a skewer into a cylinder; they were then lapped over at the seam, and welded at a white heat. The most ductile and tenacious soft iron, free from all blemishes, must be selected for this slip. It is frequently welded at the common forge, but a proper air-furnace answers better, not being so apt to burn the iron, which should be covered with ashes or cinders. The shape of the bore is given by hammering the cylinder upon a steel mandril, in a groove of the anvil. Six inches of the barrel at either end are left open for forming the breech and the muzzle by a subsequent welding operation; the extremity put into the fire being stopped with clay, to prevent the introduction of cinders. For every length of two inches, there are from two to three welding operations, divided into alternating high and low heats; the latter being intended to correct the defects of the former. The breech and muzzle are not welded upon the mandril, but upon the horn of the anvil; the breech being thicker in the metal, is more highly heated, and is made somewhat wider to save labour to the borer. The barrel is finally hammered in the groove of the anvil without the mandril, during which process it receives a heat every two minutes. In welding, the barrel extends about one-third in length; and for musquets, is eventually left from 3 to 3½ feet long; but for cavalry pistols, only 9 inches.

The best iron plates for gun-barrels are those made of *stub* iron, that is of old horse-shoe nails welded together, and forged into thin bars, or rather narrow ribands. At one time *damascus* barrels were much in vogue; they were fashioned either as above described, from plates made of bars of iron and steel laid parallel, and welded together, or from ribands of the same damascus stuff coiled into a cylinder at a red heat, and then welded together at the seams. The best modern barrels for fowling-pieces and the modern rifles are constructed of stub-nail iron in this manner. The slip or fillet is only half an inch broad, or sometimes less, and is left thicker at the end which is to form the breech, and thinner at the end which is to form the muzzle, than in the intermediate portion. This fillet being moderately heated to increase its pliancy, is then lapped round the mandril in a spiral direction till a proper length of cylinder is formed; the edges being made to overlap a little in order to give them a better hold in the welding process. The coil being taken off the mandril and again heated, is struck down vertically with its muzzle end upon the anvil, whereby the spiral junctions are made closer and more uniform. It is now welded at several successive heats, hammered by horizontal strokes, called *jumping*, and brought into proper shape on the mandril. The finer barrels are made of still narrower stub-iron slips, whence they get the name of wire twist. On the continent, some barrels are made of steel wire, welded together lengthwise, then coiled spirally into a cylinder. Barrels that are to be rifled, require to be made of thicker iron, and that of the very best quality, for they would be spoiled by the least portion of scale upon their inside. Soldiers' musquets are thickened a little at the muzzle, to give a stout holding to the bayonet.

The barrels thus made are annealed with a gentle heat in a proper furnace, and slowly cooled. They are now ready for the borer, which is an oblong square *bit* of steel, pressed in its rotation against the barrel by a lip of wood applied to one of its flat sides and held in its place by a ring of metal. The boring bench works horizontally, and has a very shaky appearance, in respect at least of the bit. In some cases, however, it has been attempted to work the barrels and bits at an inclination to the horizon of 30°, in order to facilitate the discharge of the borings. The barrel is held in a slot by only one point, to allow it to humour the movements of the borer, which would otherwise be infallibly broken. The bit, as represented in *fig.* 760, has merely its square head inserted into a clamp-chuck of the lathe, and plays freely through the rest of its length.

760



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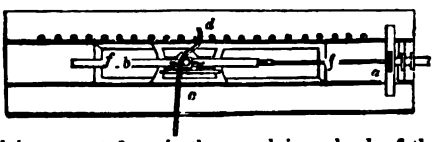

Fig. 761 represents in plan the *boring bench* for musquet barrels; *f f* is the sledge or carriage frame in which the barrel is supported; *a* is the revolving chuck of the lathe, into which the square end of the bit, *fig.* 760, is inserted; *b* is the barrel,

clamped at its middle to the carriage, and capable of being pressed onwards against the tapering bit of the borer, by the bent lever *c*, worked by the left hand of the operative against fulcrum knobs at *d*, which stand about two inches asunder. Whenever the barrel has been thereby advanced a certain space to the right, the bent end of the lever is shifted against another knob or pin. The borer appears to a stranger to be a very awkward and unsteady mechanism, but its perpetual vibrations do not affect the accuracy of the bore. The opening broach may be of a square or pentagonal form; and either gradually tapered from its thickest part, or of uniform diameter till within two inches of the end, whence it is suddenly tapered to a point.

A series of bits may be used for boring a barrel, beginning with the smallest and ending with the largest. But this multiplication of tools becomes unnecessary, by laying against the cutting part of the bit, slips of wood, called spales, of gradually increasing thickness, so that the edge is pressed by them progressively further from the axis. The bore is next polished. This is done by a bit with a very smooth edge, which is mounted as above, with a wedge of wood besmeared with a mixture of oil and emery. The inside is finished by working a cylindrical steel file quickly backwards and forwards within it, while it is revolving slowly.

In boring, the bit must be well oiled or greased, and the barrel must be kept cool by letting water trickle on it; for the bit, revolving at the rate of 120 or 140 times a minute, generates a great deal of heat. If a flaw be detected in the barrel during the boring, that part is hammered in, and then the bit is employed to turn it out.

Many sportsmen are of opinion that a barrel with a bore somewhat narrowed towards the muzzle serves to keep shot better together; and that roughening its inside with pounded glass has a good effect, with the same view. For this purpose, also, fine spiral lines have been made in their interior surface. The justness of the calibre of a fowling-piece or musket is tried by means of a truly turned cylinder of steel, 3 or 4 inches long, which ought to move without friction, but with uniform contact from end to end of the barrel. Whatever irregularities appear must be immediately removed.

The outer surface of the barrel is commonly polished upon a dry grindstone, but it is better finished at a turning lathe with a slide rest.

Rifle barrels have parallel grooves of a square or angular form cut within them, each groove being drawn in succession. These grooves run spirally, and form each an aliquot part of a revolution from the chamber to the muzzle. Rifles should not be too deeply indented; only so much as to prevent the ball turning round within the barrel, and the spires should be truly parallel, that the ball may glide along with a regular pace.

The Parisian gun-makers, who are reckoned very expert, draw out the iron for the barrels at hand forges, in fillets only one-ninth of an inch thick, one inch and a half broad, and four feet long. Twenty-five of these ribands are laid upon each other, between two similar ones of double thickness, and the bundle, weighing 60 lbs., bound with wire at two places, serves to make two barrels. The thicker plates are intended to protect the thinner from the violence of the fire in the numerous successive heats necessary to complete the welding, and to form the bundle into a bar two-thirds of an inch broad, by half an inch thick; the direction of the individual plates relatively to the breadth being preserved. This bar folded flat upon itself, is again wrought at the forge, till it is only half an inch broad, and a quarter of an inch thick, while the plates of the primitive ribands are now set perpendicular to the breadth of the narrow fillet; the length of which must be 15 or 16 feet French (16 or 17 English), to form a fowling piece from 28 to 30 inches long. This fillet, heated to a cherry red in successive portions, is coiled into as close a spiral as possible, upon a mandril about two-fifths of an inch in diameter. The mandril has at one end a stout head for drawing it out, by means of the hammer and the grooves of the anvil, previous to every heating. The welding is performed upon a mandril introduced after each heat; the middle of the barrel being first worked, while the fillets are forced back against each other, along the surface of the mandril, to secure their perfect union. The original plates having in the formation of the ultimate long riband become very thin, appear upon the surface of the barrel like threads of a fine screw, with blackish tints to mark the junctions. In making a double-barrelled gun, the two are formed from the same bundle of slips, the coils of the one finished fillet being turned to the right hand, and those of the other to the left.

The barrels forged, as above described, from a bundle of steel and iron plates laid alternately together, are twisted at the forge several times, then coiled and welded as usual. Fifteen workmen concur in one operation: six at the forge; two at the boring mill; seven at filing, turning, and adjusting; yet altogether make only six pairs of barrels per week. In the first instance, it will be understood, that, for the

construction of the superior barrels, a bundle of horse-shoe nails is welded into a flat bar, similar bars of scrap steel are made, and these are made up into a bundle,—a bar of iron, and a bar of steel—of eight or twelve bars. This is again welded into one bar, and the result is, when the surface is polished, that the difference in the texture of the two metals is distinctly visible. Now, if two bars of iron and one of steel, or two bars of steel and one of iron, or any other combination of the two, be adopted, there will be a variety in the pattern of the finished bar.

In constructing the barrel this bar may be twisted up singly, as described, or two bars differing in pattern may be welded together, and then twisted. It is usual to place two bars together, to twist one into a screw and leave the other plain, or to give one a right hand twist and the other a left handed one, or sometimes three bars are employed, and by twisting or otherwise previously to welding the bars together and turning or twisting the compound bar into a cylinder, a great variety of patterns are produced on the finished barrel.

The breeching is of three kinds: the common; the chamber, plug, or mortar, *fig.* 762; and the patent, *fig.* 763. The common was formerly used for soldiers' musquets and inferior pieces. The second is a trifling improvement upon it. In the patent breeching, the screws do not interfere with the touch-hole, and the ignition is quicker in the main chamber.

763

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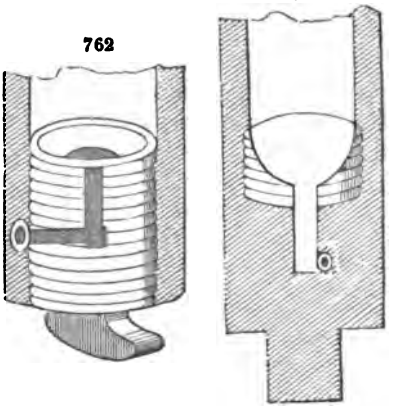
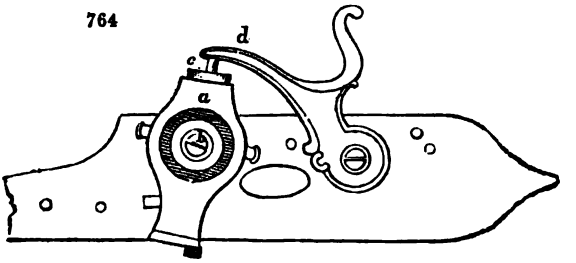


The only locks which it is worth while to describe are those upon the percussion principle, as flint locks have ceased to be employed. Forsyth's lock (*fig.* 764) was an ingenious contrivance. It has a magazine *a*, for containing the detonating powder, which revolves round a roller *b*, whose end is screwed into the breech of the barrel. The priming powder passes through a small hole in the roller, which leads to a channel in communication with the chamber of the gun.

The pan for holding the priming is placed immediately over the little hole in the roller. There is a steel punch *c*, in the magazine, whose under end stands above the pan, ready to ignite the priming when struck upon the top by the cock *d*, whenever the trigger is drawn. The punch, immediately after being driven down

764



into the pan, is raised by the action of a spiral spring. For each explosion, the magazine must be turned so far round as to let fall a portion of the percussion powder into the pan; after which it is turned back, and the steel punch recovers its proper position for striking another blow into the pan.

The invention of the copper percussion cap was another great improvement upon the detonating plan. *Fig.* 765 represents the ordinary percussion lock, which is happily divested of three awkward projections upon the flint lock, namely, the hammer, hammer spring, and the pan. Nothing now appears upon the plate of the lock, but the cock or striking hammer, which inflicts the striking blow upon the percussion cap. It is concave, with a small metallic ring or border, called a shield or fence, for the purpose of enclosing the cap, as it were, and preventing its splinters doing injury to the sportsman, as also protecting against the line of flame which may issue from the touch-hole in the cap-nipple. This is screwed into the patent breech, and is perforated with a small hole.

The safety lock of Dr. Somerville is, in its essential feature, a slide stop or catch,

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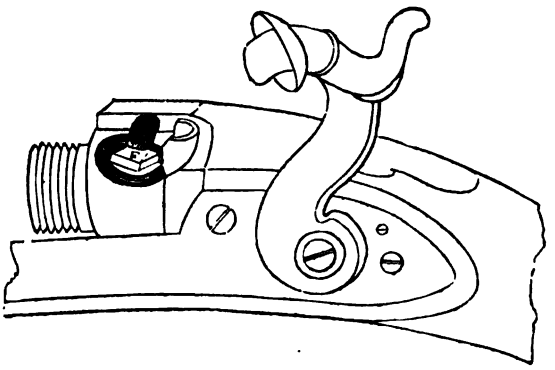

placed under the trigger, A, *fig.* 766. It is pulled forward into a notch in the trigger, by means of a spring B, upon the front of the guard, which is worked by a key C,

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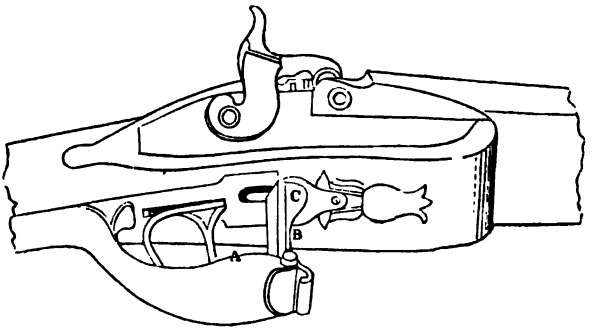

pressing upon the spring when the piece is discharged. In another safety plan there is a small movable curved piece of iron, A, which rises through an opening B, in the lock-plate C, and prevents the cock from reaching the nipple, as represented in the figure, until it is drawn back within the plate of the lock when the piece is fired.

To fire this gun, two different points must be pressed at the same time. If by accident the key which works the safety be touched, nothing happens, because the trigger is not drawn; and the trigger touched alone can produce no effect, because it is locked. The pressure must be applied to the trigger and the key at the same instant, otherwise the lock will not work.

The old French musket is longer than the British, in the proportion of 44·72 inches to 42; but the French bayonet is 15 inches, whereas the British is 17.

	Eng. Dimensions.	Fr. Dimensions.
Diameter of the Bore - - - -	0·75 in.	0·69 in.
Diameter of the ball - - - -	0·676	0·65
Weight of the ball in oz. - - -	1·06	0·958
Weight of the firelock and bayonet in lbs.	12·25	10·980
Length of the barrel and bayonet - -	59·00	59·72

Within these few years a great many contrivances for fire arms have been brought forward, and several have been patented. The first is that of Charles Random, Baron de Berenger. *Fig.* 767 shows the lock and breech of a fowling piece, with a sliding protector on one of the improved plans; *a* is the hammer, *b* the nipple of the touch-hole, *c* a bent lever, turning upon a pin, fixed into the lock-plate at *d*. The upper end of this bent lever stands partly under the nose of the hammer, and while in

that situation stops it from striking the nipple. A slider *g f h*, connected with the under part of the gun-stock, is attached to the tail of the bent lever at *i*; and when the

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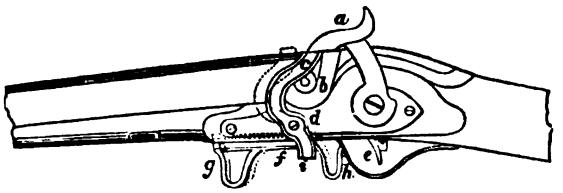

piece is brought to the shoulder for firing, the hand of the sportsman pressing against the bent part of the slider at *g*, forces this back, and thereby moves the end of the lever *c* forwards from under the nose of the cock or hammer, as shown by the dotted lines. The trigger being now drawn, the piece will be discharged; and on removing the hand from the end *g*, of the slider *f*, the spring at *h* acting against the guard, will force the slider forward, and the lever into the position first described.

Mr. Redford, gun-maker, of Birmingham, introduced a modification of the lock for small fire-arms, in which the application of pressure to the sear spring for discharging the piece is made by means of a plug, depressed by the thumb, instead of the force of the finger exerted against the trigger. *Fig.* 768 represents a fowling piece partly in

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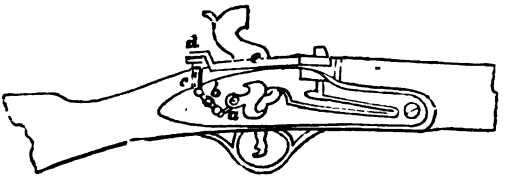

action. The sear spring is shown at *a*. It is not here connected with the trigger as in other locks; but is attached by a double-jointed piece to a lever *b*, which turns upon a fulcrum pin in its centre. At the reverse end of this lever an arm extends forwards, like that of an ordinary sear spring, upon which arm the lower end of the plug *c* is intended to bear; and when this plug is depressed by the thumb bearing upon it, that end of the lever *b* will be forced downwards, and the reverse end will be raised, so as to draw up the end of the sear spring, and set off the piece. For the sake of protection, the head of the plug *c* is covered by a movable cap *d*, forming part of a slider *e*, which moves to and fro in a groove in the stock, behind the breech end of the barrel; this slider *e* is acted upon by the trigger through levers, which might be attached to the other side of the lock-plate; but are not shown in this figure to avoid confusion. When the piece is brought to the shoulder for firing, the fore-finger must be applied as usual to the trigger, but merely for the purpose of drawing back the slider *e*, and uncovering the head of the plug; when this is done, the thumb is to be pressed upon the head of the plug, and will thus discharge the piece. A spring bearing against the lever of the slider *e*, will, when the finger is withdrawn from the trigger, send the slider forward again, and cover the head of the plug, as shown.

The Rev. John Somerville, of Currie, in April, 1835, obtained a patent for a further invention to prevent the accidental discharge of fire-arms. It consists in hindering the hammer from reaching the nipple of a percussion lock, or the flint reaching the steel of an ordinary one, by the interposition of movable safety studs or pins, which protrude from under the false breech before the hammers of the locks, and prevent them from descending to strike. These safety studs or pins are moved out of the way by the pressure of the right hand of the person using the gun only when in the act of firing, that is, when the force of the right hand and arm is exerted to press the butt end of the stock of the gun against the shoulder while the aim is taken and the trigger pulled. In carrying the gun at rest, the proper parts of the thumb or hand do not come over Mr. Somerville's movable buttons or studs.

Fig. 769 is a side view of part of a double percussion gun; and *fig.* 770 is a top or plan view, which will serve to explain these improvements, and show one, out of many, methods of carrying them into effect. A is the stock of the gun; B the barrels; C the breech; D the nipples; E the false breech, on the under side of which the levers which

work the safety studs or pins are placed; F is the shield of the false breech; G triggers; H the lock-plate; and I the hammers: all of which are constructed as usual: *a a* are

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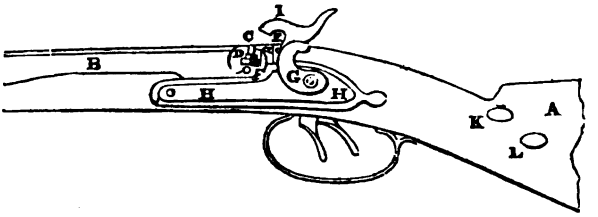

the safety studs or pins, which protrude before the shield F, and work through guide pieces on the under side of the false breech. The button piece is placed in the

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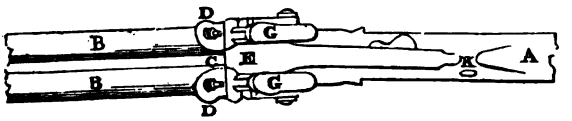

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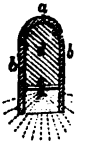

position for the thumb of the right hand to act upon it; but when the pressure of the ball of the right thumb is to produce the movement of the safety studs, it must be placed in or near the position K; and when the heel of the right hand is to effect the movements of the safety studs, the button piece must be placed at L, or nearly so.

In these last two positions, the lever (which is acted upon by the button piece to work the safety studs through a slide) would require to be of a different shape and differently mounted. When the hammers are down upon the nipples after discharging the gun, the ends of the safety pins press against the inner sides of the hammers. When this invention is adapted to single-barrelled guns, only one pin, *a*, one lever and button piece will be required.

Mr. Richards, gun-maker, Birmingham, patented a modification of the copper cap for holding the percussion powder as represented *fig.* 771; in which the powder is removed from the top of the cap, and brought nearer the mouth; *a* being the top, *b* the sides, and *c* the position of the priming. The dotted lines show the direction of the explosion, whereby it is seen that the metal case is opened or distended only in a small degree, and not likely to burst to pieces, as in the common caps, the space between *a* and *c* being occupied by a piece of any kind of hard metal *d*, soldered or otherwise fastened in the cap.

George Lovell, Esq., Director of the Royal Manufactory of Arms at Enfield, introduced an improvement upon the priming chamber. He forms it into a vertical double cone, joined in the middle by the common apex; the base of the upper cone being in contact with the percussion cap, presents the most extensive surface to the fulminate upon the one hand, while the base of the under one being in a line with the interior surface of the barrel, presents the largest surface to the gunpowder charge, upon the other. In the old nipple the apex of the cone being at its top, afforded very injudiciously the *minimum* surface to the exploding force.

Guns, Rifling of the Barrels.—The outside of rifle barrels is, in general, octagonal. After the barrel is bored, and rendered truly cylindrical, it is fixed upon the rifling machine. This instrument is formed upon a square plank of wood 7 feet long, to which is fitted a tube about an inch in diameter, with spiral grooves deeply cut internally through its whole length; and to this a circular plate is attached about 5 inches diameter, accurately divided in concentric circles, into from 5 to 16 equal parts, and supported by two rings made fast to the plank, in which rings it revolves. An arm connected with the dividing graduated plate, and pierced with holes, through which a pin is passed, regulates the change of the tube in giving the desired number of grooves to the barrel. An iron rod, with a movable handle at the one end, and a steel cutter in the other, passes through the above rifling tube. The rod is covered with a core of lead one foot long. The barrel is firmly fixed by two rings on the plank, standing in a straight line on the tube. The rod is now drawn repeatedly through the barrel, from end to end, until the cutter has formed one groove of the proper depth. The pin is

then shifted to another hole in the dividing plate, and the operation of grooving is repeated till the whole number of riflings is completed. The barrel is next taken out of the machine, and finished. This is done by casting upon the end of a small iron rod a core of lead, which, when besmeared with a mixture of fine emery and oil, is drawn, for a considerable time, by the workmen, from the one end of the barrel to the other, till the inner surface has become finely polished. The best degree of spirality is found to be from a quarter to half a revolution in a length of three feet.

Military Rifles. — An essential improvement in this destructive arm has been introduced into the British service.

The intention in all rifles is to impart to the ball a rotatory or spinning motion round its axis, as it passes out through the barrel. This object was attained, to a certain degree, in the rifles of the old pattern, by cutting seven spiral grooves into the inside of the barrel, in the manner shown by *fig.* 772, the spherical ball, *fig.* 773, being a little larger than the bore, was driven down with a mallet, by which the projecting ribs were forced into the surface of the ball, so as to keep it in contact with their curvatures, during its expulsion. Instead of this laborious and insecure process, the barrel being now cut with only two opposite grooves, *fig.* 774, and the ball being formed with a projecting belt, or zone, round its equator, of the same form as the two grooves, *fig.* 775, it enters so readily into these hollows, that little or no force is required to press it down upon the powder. So much more hold of the barrel is at the same time obtained, that instead of one *quarter* of a turn, which was the utmost that could be

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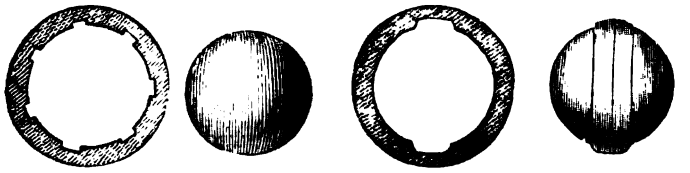

safely given in the old way, without danger of stripping the ball, a *whole* turn round the barrel in its length, can be given to the two grooved rifles; whereby a far more certain and complete rotatory motion is imparted to the ball. The grand practical result is, that better practice has been performed by several companies of the Rifle Corps, at 300 yards, than could be produced with the best old military rifles at 150 yards; the soldier being meanwhile enabled to load with much greater ease and despatch. The belt is bevelled to its middle line, and not so flat as shown in the figure.

This mode of rifling is not, however, new in England. In fact, it is one of the oldest upon record; and appears to have fallen into disuse from faults in the execution. The idea was revived within the last few years in Brunswick, and it was tried in Hanover also, but with a lens-shaped (*Linsenförmig*) ball. The judicious modifications and improvements it has finally received, have brought out all its advantages, and rendered it, when skilfully used, a weapon of unerring aim, even at the distance of 700 yards.

The locks, also, for the military service generally, are receiving important im-

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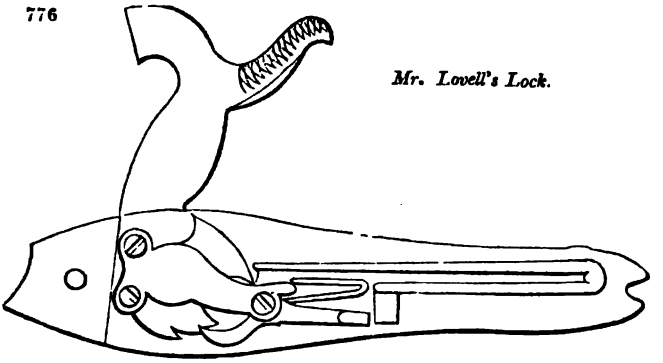

Mr. Lovell's Lock.

provements. In Lovell's lock the action of the main spring is reversed, as shown by *fig.* 776; thus rendering the whole mechanism more solid, compact, and convenient;

while the ignition of the charge is effected by percussion powders in a copper cap. Mr. Lovell, inspector of small arms for her Majesty's service, and director of the Royal manufactory, at Enfield Chase, directed his mind to the construction of a sure, simple, and strong musket, with which, under his superintendence, the whole of her Majesty's soldiers were long provided. He has also furnished them with a short, but clear set of instructions for the cleaning and management of these excellent arms, illustrated by a series of wood engravings. From this little work the following notice is copied.

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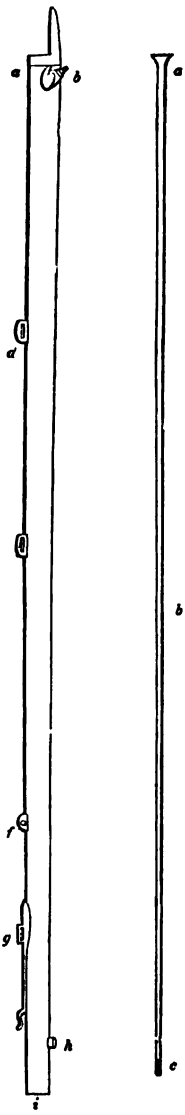

Fig. 777. The barrel, reduced to one-seventh size. *a*, the breech; *b*, the nipple-seat or lump; *c*, the back sight; *d*, the back-loop; *e*, the middle loop; *f*, the swivel-loop; *g*, the front loop, with the bayonet-spring attached; *h*, the front sight; *i*, the muzzle.

Fig. 778. The breech-pin, half size. *a*, the tang; *b*, the neck; *c*, the screw threads; *d*, the face.

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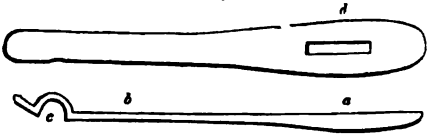

Fig. 779. The bayonet-spring, two ways, half size. *a*, the shank; *b*, the neck; *c*, the hook; *d*, the mortice.

Fig. 780. The nipple, full size. *a*, the cone; *b*, the squares; *c*, the shoulder; *d*, the screw-threads; *e*, the touch-hole.

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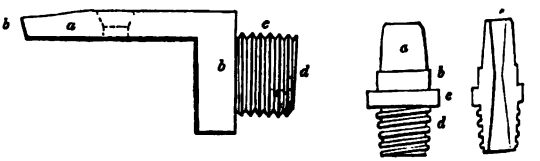

Fig. 781. The rammer reduced to one-seventh size. *a*, the head; *b*, the shaft; *c*, the screw threads.

Fig. 782. The lock, outside, half size. *a*, the plate; *b*, the cock; *c*, the tumbler-pin; *d*, the hollow for the nipple seat.

Fig. 783. The lock, inside, half size, showing all the parts in their places with the cock down at bearer. *a*, the main-spring; *b*, the sear-spring; *c*, the sear; *d*, the tumbler; *e*, the bridle; *f*, the main-spring-pin; *g*, the sear-pin; *h*, the sear-spring-pin; *i*, the bridle-pin.

Barrel-welding by Machinery. — The barrels of musquets, birding-guns, &c., or what are called *plain*, to distinguish them from those denominated *stub* or twisted barrels, have of late years been formed by means of rolls, a process in which the welding is first effected on a short slab of thick iron, and then the barrel is brought down to its destined length and form, by repeatedly passing it between a pair of rolls, that have been previously grooved to the exact shape of the barrel intended to be made.

The iron being thoroughly refined, and reduced into flat bars by the process described, is cut by the shears into slabs or lengths of 10 to 12 inches, and 10 to 10½ lbs. weight, or less, according to the description of gun-barrel that is intended to be made. These slabs are then heated, and bent in their whole length, by means of conveniently goooved bending rolls, until they assume the form of rough tubes, of the kind of section shown by A, *fig.* 784. They are then placed on the hearth of the reverberatory furnace, and brought to a full welding heat, and as soon as the edges of a tube come to a semi-fluid state, it is taken out and passed between rolls having grooves somewhat smaller in diameter than the exterior of the

tube, by which means the tube is perfectly welded from end to end; and if care be taken in the management of the heat, and the juncture be kept clear of dirt and cinders, the iron will be found perfectly homogeneous in every part, and there will be no

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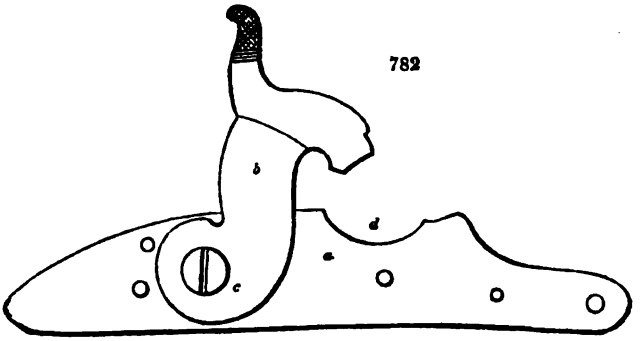

appearance whatever of the seam where the the edges came together. These tubes are repeatedly heated, and passed between the barrel rolls, which are of sufficient

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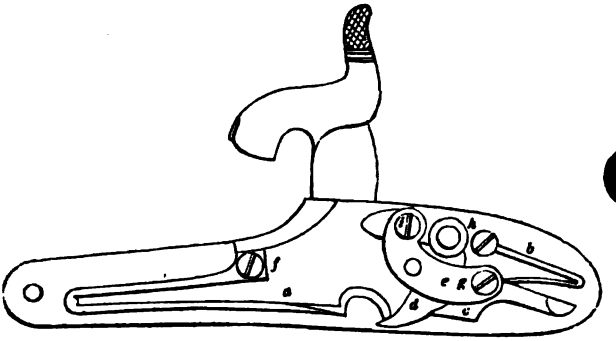

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diameter to admit of gradually decreasing grooves, the whole length of the intended barrel being indented on their surfaces.

To preserve the tubular form, and insure regularity in the size of the bore during the welding process, they are taken out of the furnace, by thrusting into them a tool called a mandril, B, *fig.* 785, which consists of a long rod of iron, having a short steel treblett on its end, of the diameter that the bore of the barrel is meant to be. This rod is so adjusted by means of a strong iron plate C, near its handle, which is of wood, and long, that when passed with the heated tube on it between two transverse holding bars, the short steel treblett D shall be found exactly between the point of impact of the barrel rolls, E, E.

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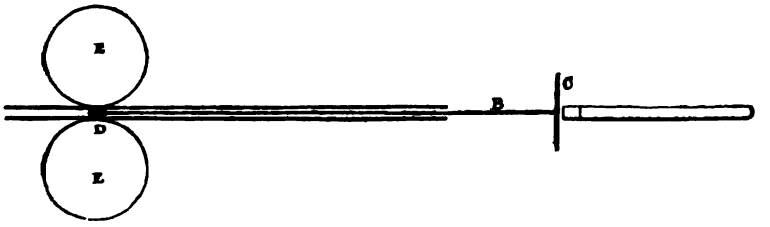

The adhesion of the hot iron to the surface of the rolls is strong enough to draw the tube off the mandril, which thus keeps the bore open from end to end, and by repeating the process through the whole series of grooves in the rolls, the barrel is

gradually elongated, and brought down to the exact form required; any superfluous length at the muzzle is then cut off. The breach end is then adjusted by the hammer — a triple-seat welded on by hand if it be intended for a percussion lock; and then the barrel is ready to go forward to the mill to be bored, turned, and finished.

Gun barrels formed by this mechanical method are found to stand proof better than those worked by hand, because the heat is more equalised; and any imperfections in the original mass of iron are more dispersed over the whole extent of the tube.

Of late years large strides have been made towards increasing the efficacy of military fire-arms.

The first attempt to inprove the rifle in use in the French army, was that proposed by M. Delvigne, an officer of the royal ex-guard (*fig.* 786), in which the upper

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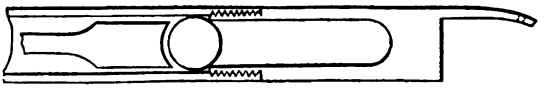

orifice of the chamber that contained the powder took the form of a cup, wherein the ball (somewhat wider in diameter) was received, and by two or three smart blows of a heavy-headed rammer (also cupped out for the purpose) became expanded laterally, and thus the rotary motion was imparted to it by the spiral grooves of the barrel in passing out. Colonel Poncharra suggested the addition of a wood bottom or sabot under the ball and a greased woollen patch; and Colonel Thouvesino proposed (*fig.* 787) a steel stem or pillar about 2 inches long inserted into the face of the breech-

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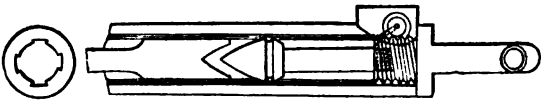

pin; round this pin the charge of powder was received, and the diameter of the ball, when resting on the top of the pin, was enlarged by the blows of the heavy-headed rammer, as suggested by Delvigue.

This system took the name of "Carabine à Tige," and has been very generally introduced for the service of fusilier battalions in continental armies; very grave objections, however, have been found against it in use, from the impossibility of keeping the chamber (or part round the pin) clear; and from the severe labour to the soldier in ramming down and enlarging the diameter of the ball sufficiently to insure the rotary motion desired.

But if the ultimate results thus attained with spherical balls turned out not entirely satisfactory, it was made clearly manifest, in the course of the experiments carried on, that no insuperable difficulty stands in the way of rendering the fire of infantry very much more accurate and powerful, by the use of rifled barrels throughout the army, and thus leading to a verification of the prediction made by Robins above one hundred years ago, that "whatever state shall thoroughly comprehend the nature and advantages of rifled barrel pieces, and having facilitated and completed their construction, shall introduce into their armies their general use, with dexterity in the management of them, will by this means acquire a superiority which will almost equal any thing that has been done at any time."

But besides smoothing the way to such an essential improvement, it has been elicited of late years, that when the accuracy of flight is secured by the rotary motion derived from the rifling, the bullet, instead of being limited to the form of a sphere as heretofore, may, up to certain limits, be elongated with considerable increase of destructive effect; and with an augmentation of range very much beyond any thing that has hitherto been considered to lie within the reach of small arms — placing them, in fact, with reference to artillery and cavalry, in the first place instead of the last.

An immensely extended field has thus been opened to experimenters. 1st. Mons. Didion proposed a true oval (*fig.* 788) as the best form of bullet, so that, when shortened by the blows of the heavy rammer and widened in its diameter, it might be brought nearer to the spherical shape before leaving the barrel.

2nd. Mons. Delvigne took a patent for a bullet (*fig.* 789) under the designation of "Cylindro Ogivale;" it had a conical opening behind, in which he imagined that the force of the powder would exert itself with sufficient energy to expand the lead permanently, and so make the ball take the rotatory movement derived from the rifling, without any fatigue to the soldier in loading: with this projectile, indeed, the operation is but slightly more difficult than with the ordinary cartridge and smooth barrels.

The bullet (*fig.* 790) of the "Carabine à Tige" was called "Cylindro Conique," and was said to possess this advantage over the preceding, that, being brought more to a point in front, it bored its way through the air with greater ease, and thus retained

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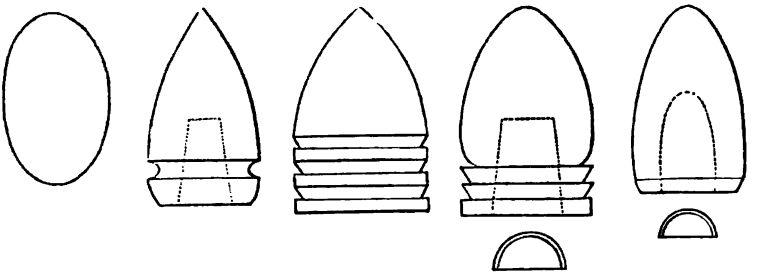

greater velocity, and of course, more extended range; and with this bullet it was that Mons. Tamisier introduced three sharp-edged channels round it, which he stated were necessary to keep its flight steady, by offering a resistance to the action of the air.

Finally Mons. Minié, an officer of the French line, suggested (*fig.* 791) the addition of a dénoyau or culot to the hollow ball of Delvigne. This, in the form of a little cup made of sheet iron, is placed in the orifice of the conical hollow of the ball behind, and by the energy of the powder is driven into the ball, enlarging its diameter permanently, and thus giving all the accuracy of the rifle, with nearly the same facility of loading as with the plain barrel.

The principle of the invention, as thus developed, has, we learn, been adopted by our government for the general use of the army, seeing that it offers so great advantages over the system of plain barrels, but the bullet (*fig.* 792), as modified by the Inspector of Small Arms, has on its exterior no channels, they being found not only useless as to steadying the flight of the projectile, but absolutely injurious in lowering its velocity. The bullet in its improved form too, being more truly balanced in its proportions, and made by mechanical means instead of by casting, has no tendency to the gyrations which appear to have so puzzled French artillerists, and for which they have invented the word "derivation," and wasted much learned disquisition.

But even if it were ever to happen, which is not likely, that these various projectors could be brought to agree as to the best form of projectile, they will then find out, that although by the general introduction of rifled and elongated bullets an immense advantage has been realised over plain barrels, their plans, based as they all are upon a system of *loading* at the *muzzle*, are at best but one step in advance; and that a good sound military fire-arm *loading* at the *breach* will, after all, remain the great desideratum — an arm that, without any less accuracy or power to reach masses of artillery or cavalry at a thousand yards' distance, will enable the soldier to triple the quantity of his fire at any moment that he may be called upon to repel a charge of cavalry or attack or defend a breach at close quarters; of such simple construction, and so easily handled in every position of the body, that the soldier can pour every shot of his most murderous fire upon the enemy with unerring precision, whilst he himself may lie coolly behind a stone or in a ditch in entire security.

These are no longer wild imaginings, although so many hundreds of attempts towards the same object, from the earliest period to the present day, have been one after another seen invariably to fail. The Germans have been long and steadily pursuing the great object, until at length Herr Dreyse, of Sömmerda in Thuringia, has succeeded, after more than twenty years of continued labour, in establishing a musquet, under the name of "Zündnadelgewehr," which if not quite perfect, is so well adapted for the uses to which it is applied that the Prussians have armed the whole of their line and the Landwehr with this weapon.

The needle musket (*fig.* 793) consists of a strong socket *a*, open on the upper side

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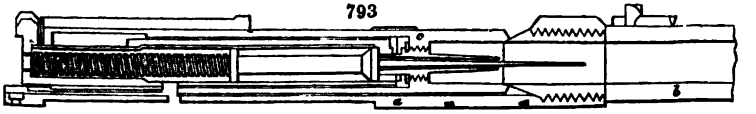

and screwed on to the barrel *b*, which is rifled in the usual manner; within this socket is a slider *c*, which in fact constitutes the lock, as it contains the spiral spring and

mechanism that produce ignition by percussion; it has a stout hebel, or handle, by which it is moved backwards and forwards freely. The cartridge (*fig.* 794) consists of the ball *a*, the sabot *b*, or bottom of hard paper, and holding the priming matter, and lastly the charge of powder *c*, the whole being made up in paper pasted together. In use the slider being drawn back, the soldier puts the cartridge with the point of the ball in front into the open breach of the barrel, pushes the slider forward, and secures its close junction by a turn to the right against an inclined edge of the open socket. The spiral spring is then brought into action by pressing the spring case forward with the thumb.

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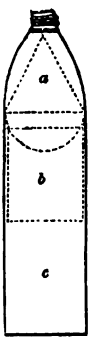


To Captain Drayson, R. A., we are indebted for the following. The Enfield rifle, which has lately been approved of for the use of the army, is constructed principally by machinery.

The factory at Enfield, at which this arm is manufactured, is considered one of the most complete establishments in the world.

The barrel, lock, wood-work, furniture, and bayonet are all constructed at Enfield, and as each portion is made exactly of the same size and shape, a part of one rifle will fit into the same part of another.

The total length of this weapon, including bayonet, is 6 ft. 0½ in. long, and weighs 9 lb. 3 oz.; the barrel is 3 ft. 3 in. in length, and weighs 4 lb. 2 oz.; the diameter of bore is ·577 inch. The bullet is elongated, and rotates on leaving the piece like a spherical bullet. The general figure of the bullet is cylindrical, but its front end is rounded, and its rear end has a conical-shaped cavity. In the Minie rifle, some of which were introduced into the service, a small iron cap was placed in the hollow at the rear end of the ball for the purpose of causing the bullet to expand, but in the Enfield rifle this opening is filled by a wooden plug instead. This diminishes the fouling of the bore, and answers all the purposes of expansion.

The bullet is ·568 inch, length 1·062 inch, weight 530 grains. The barrel is proved at Enfield, and when flaws are supposed to exist as much as 15 drams of powder have been fired, without bursting the barrel. The service charge is 2½ drams. The weight of 60 rounds of ammunition including 75 caps is 5 lb. 8 oz.

The bore has three grooves, each groove forms a spiral of ¼ a turn in 3 feet 3 inches. The rifle is sighted up to 900 yards, but an effective range may be obtained beyond that distance.

The number of rifles lately turned out at Enfield is from 1000 to 1200 per week; but there is shortly to be an increase in this quantity, when it is expected that upwards of 1500 per week will be turned out.

For neatness and completeness of workmanship, as well as for efficiency, the Enfield rifle is undoubtedly superior to any other fire-arm yet in use.

FIRE BRICKS. See BRICKS and CLAY.

FIRE-DAMP; the carburetted hydrogen of coal-mines, produced, in some cases, by the slow decomposition of the coal itself; in others, it is probably the result of the changes in the constitution of the vegetable matter of which the coal itself is formed, which has been confined under great pressure in the interstitial spaces of the coal beds or rocks immediately in connection with them. The accumulation of this gas in the "goaf," or waste spaces of a coal mine, is probably due to the changes which the coal itself undergoes. The sudden outbursts of this gas, known as "blowers," are no doubt the result of the liberation of the gas by suddenly removing the pressure under which it has been confined. This gas is the constant product of the decomposition of carbonaceous bodies under water; it has hence been also called marsh gas. It is a protocarburetted hydrogen, its formula being C^2H^4.

This carburetted hydrogen gas does not explode when mixed with air in a proportion much above or below the quantity necessary for complete combustion. With three or four times its volume of air it does not explode at all, with five and a half or six volumes of air it detonates feebly, and with seven or eight most powerfully. When mixed with fourteen volumes of air the mixture is still explosive, but with larger proportions of air the gas only burns about the flame of the taper. See SAFETY LAMP and MINING.

FIRESTONE, signifies a stone which will bear the heat of a furnace without injury. In geology the term is generally applied to the sandstone which occurs at the top of the upper green sand in the south of England, which, from its power of withstanding the effects of heat, is frequently used for lining kilns and furnaces. It is a greenish calcareous sandstone, soft, and easily worked in any direction when first taken from the quarry; but on exposure it becomes extremely hard and durable, and well suited for building purposes. Many of the older churches in Dorsetshire are built of this stone.—H. W. B.

FIRE WORKS, See PYROTECHNY.

FIR-WOOD. (*Abies.*) 1. THE SILVER FIR, *Pinus abies.* (*Sapin Commun*, Fr.; *Weiss Oder Edel Tanne*, Germ.) 2. SCOTS FIR, *Pinus sylvestris.* (*Pin D'Ecosse*, Fr.; *Kiefer Oder Föhre*, Germ.) These are valuable as timber-trees, and for the resinous juices which exude from them.

FISH SKIN. The skin of the dog-fish, shark, and other ganoids, used occasionally in polishing and in cleaning rounded and irregular works in pattern making.

FLAGSTONE: a stone which splits freely in a particular direction along the original lines of deposition of the rock. These are generally sandstones, and the splitting surfaces are frequently produced by thin laminæ of mica; but thin bedded limestones also furnish flagstones, of which some beds of Purbeck limestone and the Stonefield slates are examples. Flagstones are also obtained from Lias limestones, which are, in fact, thin beds of indurated clay.—H. W. B.

FLAKE WHITE. This name is applied indiscriminately to pure white lead, and to the trisnitrite of bismuth.

FLAME (*Flamme*, Fr. and Germ.), in the ordinary acceptation, is the combustion of a mixture of an inflammable gas or vapour with air. That it is not, as many suppose, combustion merely at the exterior surface where the gas and the air come in contact with each other, is proved by passing a fragment of phosphorus or sulphur into the centre of a large flame. Either of these bodies ignited in passing through the film of flame will continue to burn there with its peculiar light; thus proving that oxygen is mixed with the vapour in the interior. If we mix good coal gas with as much atmospheric air as can convert all its carbon into carbonic acid, the mixture will explode with a feeble blue light; but if we mix the same gas with a small quantity of air, it will burn with a rich white flame; a knowledge of this fact has led to the practice, in many of our large gas works, of pumping air into the gasometers with the coal gas, a dishonest and a dangerous system. In the latter case, the carbonaceous particles are precipitated, as Sir H. Davy first showed, in the interior of the flame, become incandescent, and constitute *white light:* for from the ignition of solid matter alone can the prismatic rays be emitted in that concentrated union. Towards the interior of the flame of a candle, a lamp, or a gas jet, where the air is scanty, there is a deposition of solid charcoal, which, by its ignition, increases in a high degree the intensity of the light. If we hold a piece of fine wire gauze over a jet of coal gas close to the orifice, and if we then kindle the gas, it will burn above the wire with its natural brilliancy; but if we elevate the gauze progressively higher, so as to mix more and more air with it before it reaches the burning point, its flame will become fainter and less white. At a certain distance it becomes blue, like that of the above explosive mixture. If a few platina wires be held in that dim flame they will grow instantly white hot, and illuminate the apartment. On reversing the order of this experiment, by lowering progressively a flat piece of wire gauze from the summit towards the base of a gas flame, we shall find no charcoal deposited at its top, because plenty of air has been introduced there to convert all the carbon of the gas into carbonic acid; but as we descend, more and more charcoal will appear upon the meshes. At the very bottom, indeed, where the atmospheric air impinges upon the gauze, the flame is blue, and no charcoal can therefore be deposited.

The fact of the increase of the brilliancy and whiteness of flame by the development and ignition of solid matter in its bosom, illustrates many curious phenomena. We can thus explain why olefiant gas affords the most vivid illumination of all the gases; because, being surcharged with charcoal, its hydrogen lets it go in the middle of the flame, as it does in an ignited porcelain tube, whereby its solid particles first get ignited to whiteness, and then burn away. When phosphorus is inflamed, it always yields a pure white light, from the ignition of the solid particles of volatilised phosphorus rapidly converted to phosphoric acid.

In the blowpipe flame from an oil-lamp or a candle, the inner blue flame has the greatest heat, because there the combustion of the whole fatty vapour is complete. The feeble light of burning hydrogen, carbonic oxide, and sulphur, may, upon the principles now expounded, be increased by simply placing in them a few particles of oxide of zinc, slender filaments of amianthus, or fine platina wire. Upwards of twenty years ago Dr. Ure demonstrated, in his public lectures in Glasgow, that by narrowing the top of a long glass chimney over an argand flame either from oil or coal gas, the light could be doubled, at the same cost of material. The very tall chimneys used by the lamp-makers are very wasteful, as they generate a strong current of air, and the combustion of the solid matter is carried on with great rapidity. With a narrow chimney of half the length we can have nearly as good a light, and save 30 per cent. of the oil. See BLOWPIPE.

FLANDERS BRICKS, commonly called Bath bricks. These are made in large quantities at Bridgewater, from the silty clay deposited in the estuary, which contains

a large quantity of fine sand. These bricks are much used for domestic purposes, also in making founders' cores, and for polishing some steel articles.

FLANNEL. A plain woollen stuff of a rather open and slight fabric. See WOOLLEN MANUFACTURES.

Wales is the country in which flannel was originally made, and the Welsh flannel is still held in much estimation. Hand labour is still employed in the production of Welsh flannel, and though it is not so cheap as some others, the quality and finish of this fabric generally causes it to be preferred for vests worn next the skin and similar purposes. Flannels are now made more extensively at Rochdale than in any other part of the world. In that neighbourhood the manufacturers produce the greatest variety of widths, finish, and substance, viz.: the thin, the medium, the thick, double raised, and swanskin. Saddleworth produces the so-called Saxony flannels, which are much admired, and some varieties are produced at Leeds, and finished the natural colour of the wool. In the west of England flannels are made, but not extensively, and in Ireland a few varieties of low flannels and coatings, called Galways, are manufactured from Irish grown wool.

FLAT RODS. In mining, a series of rods for communicating motion from the engine, horizontally, to the pumps or other machinery in a distant shaft.

FLAX (Latin, *linum*; French, *lin*; Italian and Spanish, *lino*; Portuguese, *linho*; German *flachs*; Dutch *vlas*), the *Linum usitatissimum*, a plant of the class Pentandria, order Pentagynia, in the system of Linnæus, and the type of the order Linaceæ, in the natural system of Botany, largely cultivated for its fibre and seed, and, next to cotton, the most extensively used raw material for textile manufacture in the vegetable kingdom. This plant was primarily a native of Asia, and was introduced at an early period, into Europe. Frequent mention is made of it in scripture history, as grown both in Palestine and in Egypt, as well as of the fabrics manufactured from its fibre. It was probably introduced into Europe by the Phœnician traders, or the Greek colonists of Egypt and Syria. Homer alludes to the linen manufacture of Greece.

At the present day, the flax plant is grown for fibre alone, for seed alone, or for both products together, in many countries of the eastern, and in some of the western hemisphere. For seed alone, in Hindostan, Turkey, and the United States of America; for fibre and seed in Russia, Belgium, Holland, France, Germany, Scandinavia, Italy, Switzerland, the Iberian Peninsula, Great Britain, and Egypt; in Ireland, chiefly for the fibre, without utilising the seed.

The average annual production of fibre, in the chief countries where flax is grown, is as follows: —

	Tons.
Russia	130,000
France	48,000
Belgium	18,000
Holland	9,000
Austria	60,000
Prussia	32,000
Ireland	35,000
Egypt	10,000

and adding all other countries, we may estimate the entire annual weight of fibre produced throughout the world, at 400,000 tons.

The quantity of seed may be taken at nearly 2,000,000 of quarters. At the average value of fibre and seed, the annual production in all countries, of the former, may be given in value at 20,000,000*l.*, and of the latter at 5,000,000*l.*, making in all, 25,000,000*l.* as the worth of the raw produce, before its conversion into woven fabrics and feeding stuffs.

The flax plant has a single slender stem, varying from 2 to 4 feet in height, according to the nature of the soil and the season, with the difference of climate, and mode of culture. It has lanceolate, sessile leaves, of a rich green colour, and branches out, at the top, into two or more small stems, each of 2 or 3 inches in length, and bearing light blue flowers, succeeded by globular capsules, pointed at the apex, and bearing 8 to 10 seeds of a reddish brown, when ripe. The stem of the plant consists of an inner part, or core, sometimes hollow, but more frequently solid, composed of ligneous matter, surrounded with a bark of fibres, which are united to each other by a gum, the whole being sheathed in a fine epidermis. The plant arrives at maturity in 14 or 15 weeks after the seed is sown. It has then changed to a pale yellow or straw colour, and the seeds have become brown. The usual period of sowing, in European countries, is from March to May, although in some parts of the Continent the seed is put in the ground in autumn, but in this case nothing is gained, as the plant becomes mature very little earlier than when the sowing is done in

spring. It is grown on a wide range of soils, sandy, calcareous, clay, loam, peaty, &c., but that best adapted to it is, either a deep, friable, clay loam, or the alluvial deposit of rivers, whether along their banks, their deltas, or where reclaimed from the sea, as in the case of the polders of Holland. Deep tillage, good drainage, and repeated pulverisation of the soil, are very requisite. The preparations for the crop are begun in winter, by ploughing the surface, and turning it up to the action of frost: they are completed in spring, by plowing and harrowing. The seed is sown at the rate of 2½ bushels per statute acre, the best season being April. In the British Isles, Belgium, and Holland, the favourite seed is obtained from Russia, Riga being the port of shipment. Dutch seed is also extensively in use in Ireland, in the heavier class of soils. American is also occasionally used in Ireland, and a good deal of home grown seed—the first year's growth from Riga seed (one year from the barrel), which is considered quite equal to the parent. No manure is used in Ireland, but in Belgium and France, rape cake dissolved in urine is considered very useful. The seed is sown broadcast, and the soil is afterwards rolled. When the plant is a few inches high, weeds are carefully removed, and no further attention is necessary until the season of pulling. Flax is not cut with the scythe or sickle, but is pulled up by the roots. About the middle of August it is generally ready for pulling, in the British Islands, but in Belgium and France, it is in a fit state 2 to 3 weeks earlier.

The after treatment varies in different countries. In Russia, part of Belgium and Holland, and in France, the plant after being pulled, is dried in the sun, being set up on the root end in two thin rows, the top interlacing in the form of the letter V inverted. The sun and air soon thoroughly dry the stems, and they are then made into sheaves, and the seed afterwards beaten off. The stems are steeped subsequently. Another mode, in general use in Ireland and in part of Flanders, is to steep the green stems immediately after they are pulled. In Flanders, the seed is invariably separated from the stems before the latter are immersed in water. In Ireland, although this is practised to some extent, yet the great bulk of the flax crop is put in the water at once, with the seed capsules attached, and consequently there is a very considerable annual loss to the country, by this waste of a most valuable product of the plant. In the Walloon country of Belgium, in its eastern provinces, and in the greater part of Germany, *dew-retting* is practised. That is, in place of immersing the stems in water, they are spread thinly on short grass, and the action of the dews and rains ultimately effect what immersion in a running stream or pool accomplishes in a much shorter time, namely, the decomposition of the gum which binds the fibres to the stem and to each other. Fibre obtained by this method is, however, of very inferior quality and colour.

If the fibre of flax be separated from the stem, without the decomposition of this matter, it is found to be loaded with impurities, which are got rid of afterwards in the wet-spinning, the boiling of the yarn, the subjection of the woven fabric to the action of an alkaline lye, and the action of the atmosphere,—of rains and of alternate dippings in water, acidulated with sulphuric acid, and of a solution of chloride of lime, which are all required to perfect the bleaching. The great object, therefore, is to obtain the fibre as nearly free from all foreign substances as possible, and, consequently, the mechanical separation of it from the woody pith of the stem is not to be recommended.

At various periods attempts have been made to prepare flax fibre without steeping. Weak acids, solutions of caustic potash, and of soda, soap, lye, and lime, have all been tried, but have all been found objectionable. In 1815 Mr. Lee brought before "the trustees of the linen and hempen manufactures of Ireland" his system of separating the fibre without steeping. He alleged that a large yield was thus obtained, that the colouring matter could afterwards be discharged by the most simple means, and that the fibre possessed greater strength. But it was found that the system was practically worthless. In 1816, Mr. Pollard, of Manchester, brought forward a plan of the same nature, and proposed to make an article from flax, which could be spun on cotton machinery. This also fell to the ground. In France and Belgium, at different periods, similar projects were found equally impracticable. In 1850, and again in 1857, Mr. Donlan revived the same, but the same fatal objections prevented the success of the system. The fibre was loaded with impurities, and the apparently larger yield over steeped fibre, consisted solely of these very impurities, which had to be got rid of in the after processes of manufacture. At the same time it must be recognised that the "dry separated" fibre can be rendered useful for one class of manufactures, viz., those where no bleaching is necessary, and its great strength is here an object. For ropes, rick-covers, tarpaulins, railway-waggon covers, &c., where pitch or tar are used, and prevent the decomposing action of moisture and of atmospheric changes, this mode of obtaining flax fibre is highly useful.

The immersion of the flax stems in water, either as pulled full of sap, or after

drying, appears, as yet, to be the best mode of effecting the decomposition of the gum, and obtaining the fibre pure, or nearly so. The water most suitable for this purpose is that obtained from surface drainage, springs generally holding more or less of mineral matters in solution. Spring-water from a calcareous soil is peculiarly unsuitable, the carbonate of lime which it contains being adverse to the putrefactive fermentation of the vegetable extractive. In Russia, much of the flax grown is steeped in lakes. In Holland, it is always steeped in pools filled with the surface drainage. In France and Belgium, it is either steeped in pools or rivers. In England and Ireland, generally in pools, though occasionally in rivers. The most celebrated steep-water in the world is the river Lys, which rises in the north of France, and flows through the west of Belgium, joining the Escant at Ghent. Although the water of this stream has been analysed, chemists have not been able to discover why it should be so peculiarly favourable to the steeping of flax. All along its course flax is steeped, The trade is in the hands of factors, who purchase the dried stems from the growers, and undertake all the after processes, selling the fibre to merchants when it has been prepared for sale. The apparatus in use consists of wooden crates, 12 feet long, 8 wide, and 3 deep. The sheaves of flax-straw are placed erect in the crates, and the root ends of one are tied to the top ends of another, to secure uniformity of packing. The crate, when filled, is carried into the river, and anchored there, the upper part being sunk by the weight of stones, 6 inches underneath the surface. The period of steeping begins in May, and ends about September. The previous year's crop is thus steeped, having lain over in the state of dried straw during the winter. All the flax thus treated produces fibre of a yellowish white colour, very soft and lustrous, with very finely divided filaments, and strong. From it almost exclusively is made cambric, the finest shirtings, and damask table-linen. It is a strange fact that flax straw is brought to the Lys, from a great distance, and even from Holland, as no other water has yet been found to give such good fibre.

In 1847 a new system of steeping was introduced in Ireland, by Mr. Schenck, of New York. It had been successfully tried in America on hemp, and the inventor crossed the Atlantic to try its efficacy on flax. His plan consisted in hastening the putrefactive fermentation of the vegetable extractive by artificially raising the temperature of the water to 90° Fahrenheit. By this means instead of an uncertain period of seven to twenty-one days being required for the steep, according to the state of the weather and the temperature of the atmosphere, the flax was retted uniformly in sixty hours. The flax straw, after the separation of the seed, is placed in wooden or brick vats, and the heat is communicated by forcing steam into a coil of iron or leaden pipes, placed under a false bottom perforated with holes.

The annexed plan (*fig.* 795) of a retting on Schenck's system, capable of consuming annually the produce of 400 acres of flax, and employing, in all the operations of seeding, steeping, drying, and scutching, 30 men and 55 girls and boys, or an aggregate of 85 persons, will give an idea of the arrangements. The seeding-house requires to be of large size, as flax straw is a bulky article. It is on the ground floor, for the convenience of carting in the flax. The loft above it is used for cleaning and storing the seed. The vat and spreading-rooms are in a building of one story only, built with a vaulted roof resting on pillars. That part of the roof which is over the vats has lower windows to aid the escape of the vapours from the vats. The drying sheds at the top of the plan are on an open space, well exposed to the wind, and fifty or sixty feet apart. The hot air rooms or desiccating house are fire-proof, each room capable of containing the flax turned out in one day's work. The scutch mill, with engine and boiler-house, complete the plan.

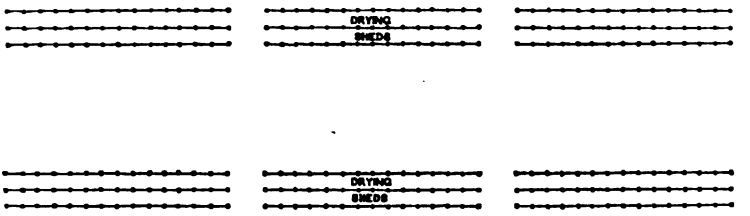
The advantages of this system were so manifest that it was speedily adopted in many parts of the United Kingdom and of the Continent. It was found, however, to have some defects. The small quantity of water soon became thoroughly saturated with the products of decomposition, and the fibre of the flax, when dried, was, consequently, found loaded with a yellow powder, offensive to the smell, causing inconvenience in the preparing and spinning, and worse still, acting prejudicially on the quality of the fibre itself, rendering it harsh and dry.

To obviate these defects, Mr. Pownall, of London, conceived the idea of pressing the flax straw, immediately when taken out of the steep, between a pair of smooth cast-iron cylinders, while, at the same time, a stream of water played upon the rollers. By these means the foul water of the vat is pressed out of the flax stems, which are flattened and bruised, thus tending to aid the separation of the bundles of fibres into minute filaments, while the stream of water effectually washed away all remaining impurities.

It has recently been found that better fibre can be obtained by reducing the temperature and extending the time of steeping. The most perfect adaptation of Schenck's system is at the rettery of M. Auguste Scrive, near Lille, and *fig.* 796 is a repre-

sentation of it. Tanks of wood or stone are used, each to contain two and a half tons of flax straw. The straw is classified according to quality and length before being packed

795



in the tank. It is put in erect, the root ends resting on the perforated false bottom, and slightly pressed together, but not so much as to prevent a free circulation of water,

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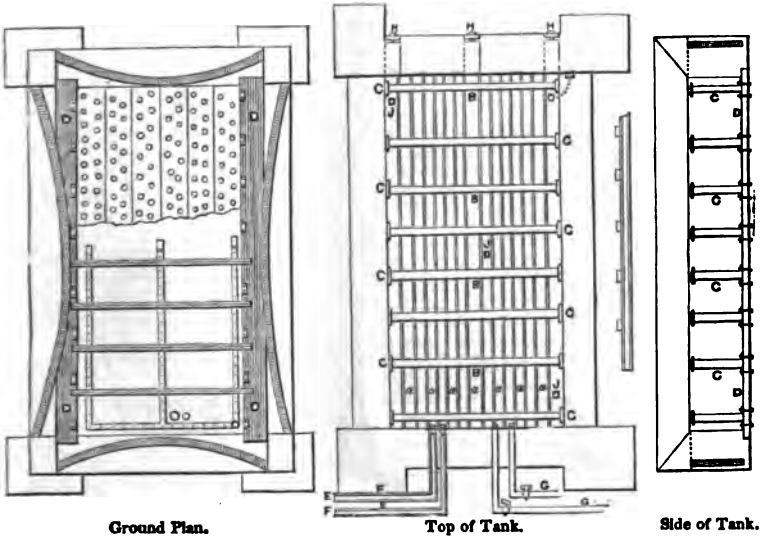

Ground Plan. Top of Tank. Side of Tank.

and a free exit for the gases germinated by the fermentation. The tank being filled with water, the whole is secured at the tops of the sheaves by narrow strips of wood

four inches thick *a*, catching the tops on the whole length of each row of bundles. These strips of wood are kept firm by cross iron holders B, secured by iron bars C, fastened to pieces of wood D, worked into the side walls of the tank, leaving a surface of four inches deep of water over the top of the flax. When the tank has been filled with cold water through the wooden shoot E, the whole is rapidly heated to 78° Fahrenheit, by means of steam pipes coiled under the false bottom. A second open shoot F, carries heated water at 90° to discharge on the surface, besides two closed pipes G G, one of which brings hot water of the same temperature, and the other cold water. When fermentation sets in, which is ordinarily in eight hours, the pipe, as well as the shoot of water at 90°, is set at play. The first to create a continual current of fresh water through the mass of flax, clearing off the products of decomposition, and bringing them to the surface; the second to drive this foul water to the openings H H, where it is discharged by the overflow. The two pipes with heated and cold water going to the bottom of the tank, as well as the two shoots containing cold and hot water, to go to the surface, are also made use of to equalise the temperature during the whole operation, which is ascertained by the use of a thermometer in the square wooden box J J. The steeping of coarse straw requires 36 to 48 hours, medium qualities 50 to 60 hours, and the finer descriptions 60 to 72 hours. The "wet rolling" between cylinders after the steep is accompanied by a shower of water at 78°, not on the flax but on the top of the cylinders. This removes the remaining impurities, and prepares the straw for being easily dried. The heated water may be obtained from the waste water of a spinning-mill, or from a condensing steam-engine.

Flax steeped by Schenck's system is dried in various ways. Some retters have drying houses with heated air, others set up the flax loosely on the root end, in the field, or spread it thinly on the grass, while others, again, clasp it between two slender pieces of wood about a yard in length, and hang these up in a building open at the sides, so that a current of atmospheric air is constantly passing through.

In 1852 another mode of retting flax was introduced by Mr. Watt, of Glasgow. Instead of immersing the stems in water, he subjected them to the action of steam. Square iron chambers were employed, in which the flax straw was packed. The door by which it was introduced was then fastened by bolts or nuts, and steam was then driven in. The steam penetrated the stems of the flax, and being partially condensed on the top and sides of the iron chamber, a constant drip of water, lukewarm, fell upon the flax. In twelve to fourteen hours the stems were removed, and, after being dried,

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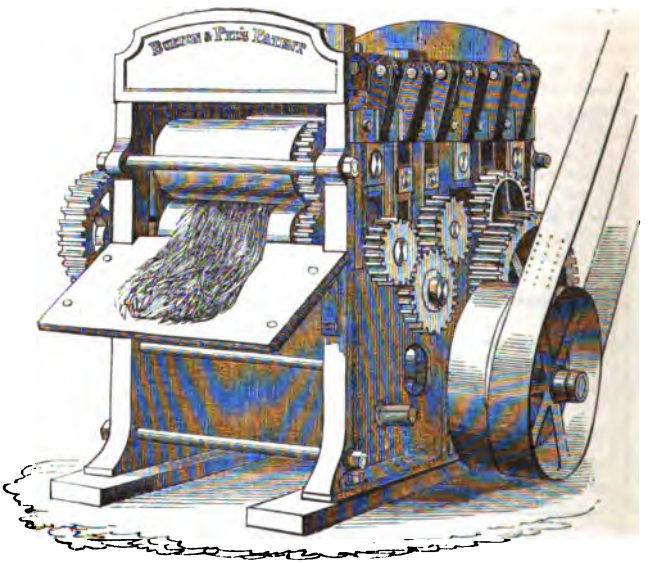


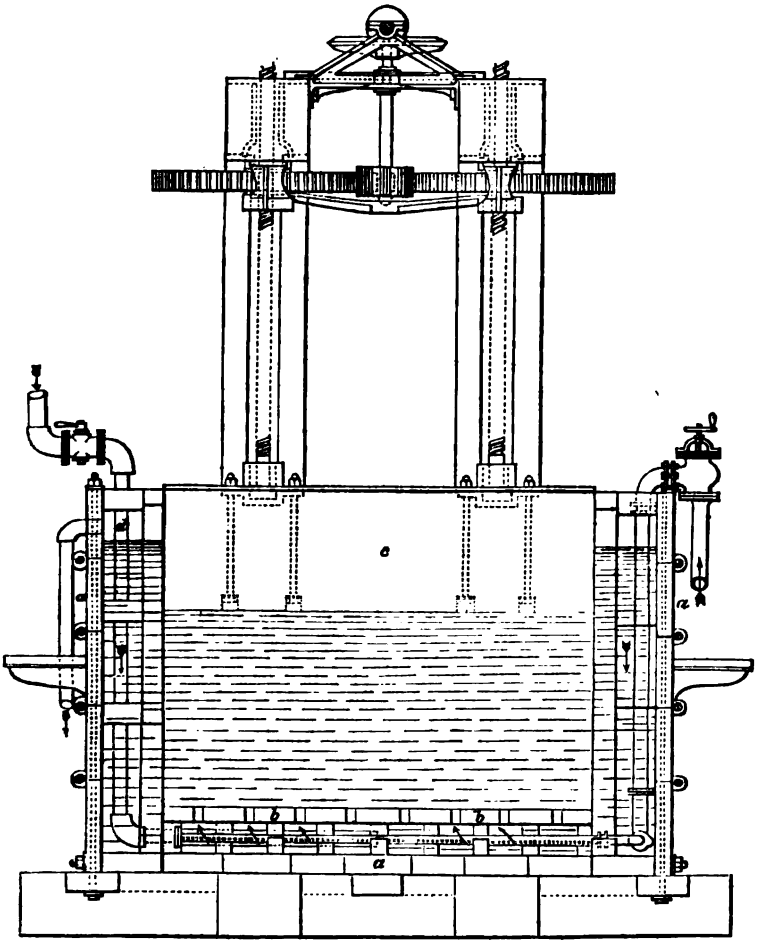
the fibre readily separated from the woody core, the water remaining in the iron chamber being of a dark brown colour, without offensive odour. The fibre obtained by

this method was of a greyish colour, and was at first well thought of by manufacturers; but, in the end, on more extended trials it was found to possess several defects, and Watt's system is not now carried out.

Another system of treating flax was introduced by M. Claussen, a Belgian, and for some time it attracted much attention. He separated the fibre from the stem without steeping, and then, by the employment of acids and alkalies, he got rid of the vegetable extractive and other impurities, and produced a fibrous mass strongly resembling cotton. He professed to make an article capable of being spun with cotton or wool. The higher value of flax fibre, however, was a great obstacle, and at present the only use made of his process is to convert scutching tow — the refuse flax fibre — into an article to be spun with wool, and even this is practised to but a very small extent.

Messrs. Burton and Pye's patent (*fig.* 797) is a modification of the hot water steep. By this process the flax straw, after the seed is removed, is passed through a machine composed of plain and crimping rollers, by the combined action of which the woody part is rendered easily separable from the fibre. The latter is then placed in a vat, holding about a ton, which is subsequently filled with cold water. This vat has a perforated false bottom, under which steam, with a pressure of 50 lbs. to an inch, is in-

798



troduced and disseminated by perforated tubes. Another tube conveys into the vat a cold mixture of fuller's earth in water. The introduction of the mixture and the steam

is continued until the liquid in the vat reaches 80° Fahrenheit. The flax remains in it at this temperature for thirty hours, when the surface of the liquid is covered with a saponaceous froth. Then an apparatus of cross bars of wood, closely fitting into the interior of the vat, and pressed by two powerful screws, expresses the impurities from the fibre. The supply of the fuller's earth is stopped, and cold water is alone supplied with the steam, so regulated that the temperature is by degrees raised to 150°, the pressure being continued until the water appears free from impurities. The water is then withdrawn from the vat through a valve in the bottom, and a pressure equal to 200 tons is applied to the mass of the flax. It remains under this pressure for four hours, when it is half dry. It is then taken out and dried in sheds open at the sides to the air. The fibre produced by Mr. Pye's method appears of good quality and strong, but the system has not as yet been carried out on a sufficiently large scale to admit of a decided opinion on its merits.

The same may be said of the plan of M. Terwangue, of Lille, who employs hot water at a temperature of 15° to 17° *centigrade*, 60° Fahr., in which chalk and charcoal have been placed. His process requires seventy-two hours on the average, and he employs brick tanks. The water is, as in all the preceding cases, heated by steam.

Before leaving the subject of steeping, reference may be made to a process patented by Mr. F. M. Jennings, of Cork, by means of which coarse flax fibre is rendered capable of being subdivided into minute filaments, or, in other words, made fine. While the fibre of cotton is incapable of subdivision, that of flax, as viewed through the microscope, is seen to consist of a bundle of extremely delicate filaments adhering together, so that fine and coarse flax are really relative terms. Mr. Jennings throws down upon the flax fibre, as it appears in commerce, a small quantity of oil, say half an ounce to the pound of fibre. He effects this by boiling the fibre in an alkaline soap lye, washing with water, and then boiling in water slightly acidulated with pyroligneous acid, which decomposes the soap and leaves its fatty constituent on the fibre. It is afterwards washed once more, and is then found to be soft and silky, and the coarse fibres capable of being readily separated on the hackle, while the strength is not apparently reduced. There is also a greater facility in the bleaching of the linen made from flax fibre so treated, and less loss in weight in the bleaching process.

While some of the inventions referred to for hastening and equalising the time of steeping are being carried out to a considerable extent, and promise well, when brought to a greater degree of perfection by experience in practical working, to be yet more largely employed, the great mass of the flax grown throughout the globe is steeped in pools, rivers, or lakes. It will, therefore, be most advisable to follow the processes, as practised by the growers or factors.

When the flax has been sufficiently retted, *i. e.* when on taking a few stalks out of the water the fibre can be readily separated by the fingers along its entire length from the woody interior, it is removed from the water, and placed to drain on the banks of the pool or river. It is then taken to a closely shorn grass-field or old pasture land, and spread thinly and evenly on the ground. In Flanders, however, the system of drying is somewhat different. Instead of being spread flat on the ground, the sheaves are divided into four portions, and these are set upright in *capelles*, *i. e.*, the butt ends are spread widely out in a circle on the ground, and the tops are kept close together. By this means the sun and air soon dry the flax. When thoroughly dried it is tied up in sheaves, and after remaining a few days in the usual form of a grain stack, it is ricked. In this state it may remain for years without the fibre being deteriorated.

The next process is termed scutching (French, *teillage*), and is intended to separate the fibre from the woody matter of the stem, and thus to make it fit for the spinner. The first part of this process is to bruise the stems thoroughly, so that while the fibre, from its tenacity, is intact, the brittle woody part is flattened and broken in such a manner as to admit of its easily being beaten off by the action of the scutch-blade or scutch-mill. In most countries the bruising is done by hand. In Flanders and France the flax straw is first laid flat on the ground, the sheaf being untied and spread thinly, and the workman, placing his foot upon it, beats it with an instrument called a *mail*, having a curved handle and a heavy square indented mallet, *fig.* 799.

The next part of the process is to give the flax repeated blows in a machine termed a *brace* or *braque*, *fig.* 800. This is generally made of wood, but sometimes of iron, and consists of two rows of grooves T T, the upper one moving on a pivot at the socket S. A stout pole P runs from end to end of the upper row of teeth. The latter are wedge-shaped, 4¾ inch deep, 1½ inches thick at top, and 33½ inches long from the head H to the socket S. The head weighs about 8 lbs. and is 10 inches long, and 3¼ inches thick. The lower row of teeth consists of four, while the upper is three, fitting into the interstices. The best wood for the machine is that of the apple-tree.

Next comes the scutching proper, still following the Belgian, French, and Dutch method of hand-work. After the flax has been bruised by the *mail*, and crushed by

the *braque*, it is ready for the scutching process. In Belgium and France the method pursued is by the employment of a wooden stand (*fig.* 801). A broad plank of

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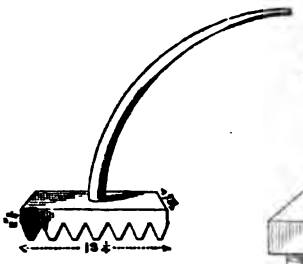

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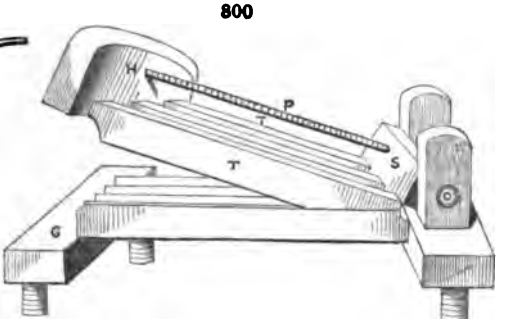
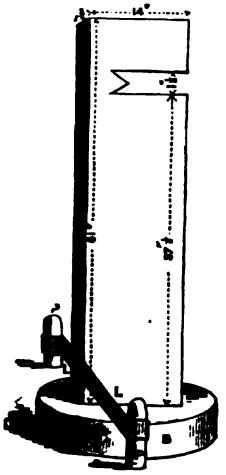


pine or beech, about 4 feet high, and rather more than a foot broad, about ¾ inch thick, is fixed in a wooden sole B. 3 feet from this sole is a cut in the wood of the upright plank, about 1½ to 2 inches wide. This cut serves for the introduction of a handful of the flax straw, bruised as before described, and the workman holding it three-

801



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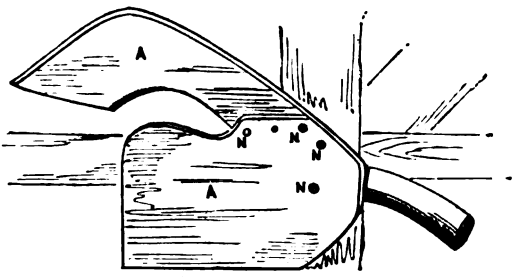

fourths exposed through the slit, beats it with a tool called the scutch-blade, *fig.* 802. It is made of walnut wood, and is very tough and flexible. In Ireland the system of scutching by hand is very rude, and prevails chiefly in the western counties. A brake similar to that of Belgium is employed, but instead of the Belgian scutch tool, a rude instrument is employed, generally of ash-wood, in the form of a sword blade.

It must be stated that the system of handscutching is only to be recommended where the quality of the flax fibre is so superior as to render economy in waste of primary importance, or else where the wages of labour are so low, as to render the power of machinery of little consequence, as regards economy. But, where wages are high, and flax of medium or low quality, there is no question that machine-scutching is the most advisable, and the most economical. This has been especially recognised in Ireland, where in 1857, 1037 scutch mills were in operation, when the growers sent their crops to be prepared for market, at a reasonable rate, much less than hand-scutching would have cost. Scutch-mills have been introduced with advantage into Russia, Prussia, Austria, Denmark, Holland, Belgium, France, Italy, and Egypt. In Ireland, although in several districts flax is scutched by hand, machine or mill scutching has been for more than half a century in operation. As in the hand-scutching, the operation consists of two processes: first, the bruising of the stems, and secondly, the beating away of the woody parts from the fibre. The original

system of bruising is still very general. It consists of a set of three smooth wooden rollers, one underneath and the two others above it, parallel to each other, and one of them horizontal to the lower roller. The labourer sits opposite the lower roller, and inserts a handful of flax straw between the latter and the upper one, which is horizontal to it. The flax being drawn in and bruised between these, passes up between the two upper rollers, and reappears at the outside. It is again put through, once or twice, according to its thickness, or to its being more or less steeped, and the fibre, consequently, more or less easily freed from the ligneous part. The scutching apparatus consists of a wooden shaft, to which are attached, at intervals, like radii of a circle, short arms, to which are nailed the *stocks*, which are parallelogram shaped blades of hard wood, with the edges partially sharpened. The labourer stands beside an upright wooden plank, very similar to that figured in the description of the Belgian hand-scutching apparatus, and through just such a slit exposes one half of the handful of bruised flax-straw to the action of the stocks, which revolve with rapidity along with the shaft, and strike the flax straw, beating off the ligneous matter, and leaving the fibre clear. When the end exposed to the stocks is cleaned, the workman turns the handful and exposes the other end. It is usual to have a set of either two or three men, at as many different stands, and instead of each thoroughly clearing out the handful of flax, he only partially does so; the second then takes it up and finishes it; or, if there be three in the set, he does not quite clean it, but hands it over to the third to do so. In the latter case, the first workman is called the *buffer*, the second the *middler*, and the third the *finisher*. The motive power in these scutch-mills is generally water; in some cases they are wind-mills, and in a few instances they are driven by horses. Latterly, the use of steam-engines has considerably increased, as being more to be depended upon than water, which frequently fails in a dry season.

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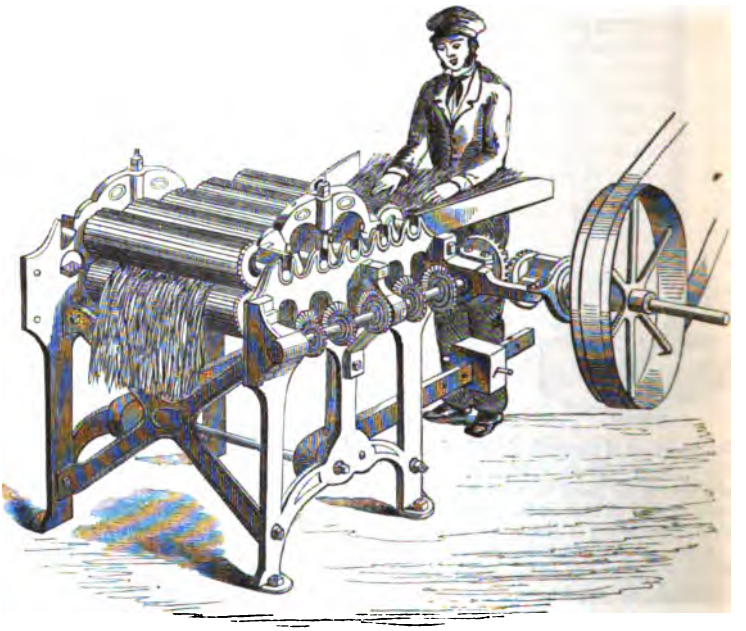

It has been found that the woody waste produced in the scutching, is quite sufficient fuel for the boiler, without its being necessary to purchase coal or peat, and this waste had hitherto been applied to no useful purpose, being with the greatest difficulty decomposable for manure.

The first improvement on this old scutch-mill apparatus was the introduction, by Messrs. MacAdam Brothers, of Belfast, of a machine for bruising the flax straw, prior to steeping, and it has since been extensively employed, with very satisfactory results. It consists of a series of fluted rollers, running vertically on each other, the flutings varying in width, the widest set being the first through which the flax straw

passes, and the others diminishing in width, until the finest is the last. While acting strongly on the ligneous matter, at the same time bruising and crimping it, and reducing it almost to powder, it does not injure or disarrange the fibres. One breaking machine of this construction is capable of supplying 12 scutching stands of the ordinary mill. It is attended by two boys, one to feed the flax-straw into the machine, by means of a feeding table, and the other to remove it at the opposite extremity. Once passing through the machine is quite sufficient to prepare the flax straw thoroughly for being scutched. The force required to drive it is one horse-power. *Fig.* 803 will best show its construction and mode of action.

It having been found that many disadvantages were inherent in the old scutch-mill, several persons have set themselves to work to supply a machine which would reduce the cost of labour, obviate the necessity of obtaining skilled workmen, and diminish the great waste of fibre, which was but too frequent in the ordinary mill. Among the most successful of these scutching-machines, is an invention of Mr. Mac-Bride, of Armagh, Ireland, *figs.* 804, 805. It consists of a cast-iron frame, at

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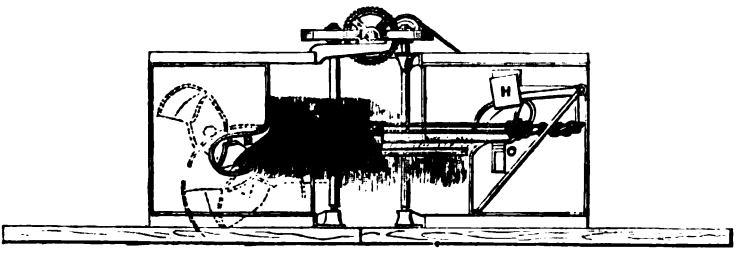

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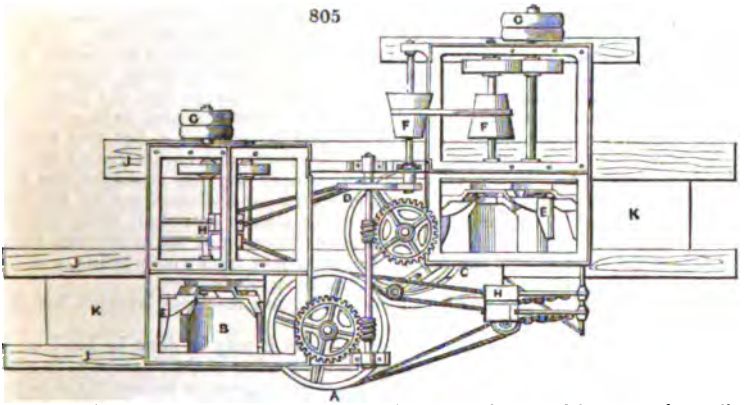

each end of which is a compartment, enclosing a double set of beaters, of peculiar construction, which revolve rapidly in a contrary direction, striking alternately on each side of the flax, as it is submitted to their action, and thoroughly removing the woody part, which falls down in dust into a pit or hollow under the machine. In order to carry the flax gradually through the machine, and present it in a proper manner to the beaters, in succession, an endless double rope is introduced, carried in the hollow of a large grooved wheel, in which it is kept tight, by means of tension weights. The flax-straw, made into handfuls, is introduced at A, under the double rope, at one end of the machine, and is at once grasped by it firmly, rather above its middle, and carried along slowly, by the movement of the grooved wheel, until it enters, hanging downwards, the compartment B, containing the first set of beaters. By the time the flax-straw has been carried through them, all its lower half, which has been exposed to the action of the beaters, is cleaned out, and the rope, passing on a short way farther, arrives at a point where a second grooved wheel is revolving, furnished with ropes in like manner, but arranged at a rather lower level. By a simple arrangement, the flax is here transferred from one set of ropes to the other, the second set grasping it near its lowest end, thus leaving all the uncleaned part, or upper half, ready to be scutched. The second wheel moves on, and carries the flax to-

wards the compartment containing the second set of beaters, cleaning all the upper portion of the flax. It then issues out at D, cleaned throughout, and is received by a person placed there for that purpose, who makes it up into the usual package for sale, 16½lbs. A constant succession of similar handfuls of flax-straw are thus kept passing through the machine without interruption. E E are the beaters, F F are two cones, carrying a leather band, which gives the motion to the ropes, or carrying apparatus. By shifting the position of this band towards one end or the other of the cones, the speed of the carrying-ropes may be varied at pleasure, so as to keep the flax a longer or shorter time under the beaters. Some kinds of flax require more scutching than others. G G are the driving pulleys, for giving motion to the machine, by means of a band from motive power, which may be steam, water, wind, or horses. Each pair of pulleys drives one set of beaters separately from the other set, and hence, if requisite to drive one set faster than the other, which is sometimes the case when the top end of the flax is hard to clean, this is easily done by using a similar pulley on the machine, or a larger drum on the driving shaft. H H are the tension weights and levers for keeping tight the carrying-ropes. J J are bearers of wood for carrying the frame of the machine. K K are pits underneath the compartments containing the beaters, and are for receiving the woody dust as it falls from the flax-straw. The machine occupies a space of 11½ feet, by 10 feet, but some space is required round it for handling the flax. The height of the machine is 6½ feet. The power required is three-horse.

M. Mertens, of Gheel, Belgium, has invented a scutching-machine, which merits notice. It is portable and cheap, and requires the attendance of only boys or girls, to put the flax-straw in and take the scutched-fibre out. The action is something similar to that of the Irish scutch-mill, but the bruised flax-straw is placed in iron clasps, one end being first cleaned out, and then the clasps opened, the flax-straw reversed, and a second insertion in the machine clears out the other end.

Messrs. Rowan, of Belfast, have very recently introduced a scutching machine, whose action differs from all hitherto in use. The flax-straw is not previously bruised, but is at once fastened in iron clasps, which are placed in a slide, the action of the machine carrying them on along one side, while two parallel bars of iron, toothed, comb the straw and separate the woody part from the fibre. The first portion of these bars have coarse teeth, and the teeth become closer by degrees up to the end of the slide. There a workman or boy takes out the clasps, unscrews the nuts fastening them, and reverses the position of the straw, so that the portion not previously subjected to the action of the machine is now presented to it, while that already cleaned out is untouched. The machine is double, *i. e.* has two sides of combs, each capable of containing twelve of the clasps, and each cleaning out one end of the flax-straw. Hence, after the workman or boy has unclasped the half-cleaned straw, turned it upside down, and presented the uncleaned end to the other side of the machine, the same action of combing, already described, clears out that end thoroughly, and by the time the progressive movement of the mechanism brings the slide to the extreme end, the flax fibre appears free from woody refuse, and in a fit state for market. It is then unclasped and made up into bundles.

There have been a great number of other scutching machines invented, but it is not necessary to particularise them.

In the operation of scutching, however carefully it may be done by hand or by machine, there occurs more or less waste, *i. e.* the beating of the flax-straw, in order to separate the marketable fibre from the useless wood, causes a portion of the former to be torn off in short filaments mingled with the wood, and this torn fibre is very much less valuable than the long filaments when finally cleared out. In general, it will not average more than an eighth or a tenth of the value of the long fibre. It is termed *scutching-tow* or *codilla*, and when properly cleaned is dry-spun for yarns employed in making coarse sacking, tarpaulins, &c. Being very much mixed with the woody-matter of the flax-stems, it is necessary to get rid of the latter before the scutching-tow can be spun into yarn. To accomplish this, shaking by hand is the first process, and subsequently the stuff is put into a woody machine termed a "devil," in which, by a mechanism something resembling the shakers in a threshing machine, the woody particles and dust are got rid of. The tow is sorted into different qualities, and, in some cases, it is *hackled* before being sold. In France and Belgium, it is chiefly retained at home, spun by hand, and woven into such fabrics as coarse trowsers and shirts, for the labouring classes, aprons, table-covers, &c. &c. What is produced in Russia, is partly used for similar purposes among the serfs, but the great mass is exported, Great Britain and Ireland being the chief mart, and Dundee especially.

The great aim in all the different methods of scutching, has been to obtain the largest possible yield of long fibre from the flax-straw, and to waste as little as pos-

sible in scutching-tow. The French and Flemish system of hand-scutching is most successful in this respect, but as the quality of fibre there produced is very much finer, and consequently more valuable than all others, the additional expense of hand-labour is compensated by the larger yield of long fibre; whereas, in Ireland, the fibre being generally coarser and less valuable, occupying an intermediate place between the Flemish and Russian, the cheapness of mill-scutching turns the scale, and, except in remote districts, it is now universal. In Egypt, until some fifteen years ago, the method of scutching was of the most primitive form. The fellahs, after steeping their flax in the Nile, and drying it on the banks, proceeded to clean out the fibre, by first beating the straw between two flat stones, and then striking it against a wooden post. Mehemet Ali and his successors, however, introduced Irish scutch mills, driven by steam-power, and since then a marked improvement has taken place in the state in which Egyptian flax has been brought to market. It may be interesting to note here, that in the early period of Egyptian civilisation, the dwellers by the Nile were able to manufacture cambrics of a finer texture than the most finished modern mechanism can produce,—as is evidenced by the cerecloths wrapping the mummies, and that from a fibre so coarse in comparison to European flax, that while the latter may be spun by machinery to 300 or 400 leas, and by hand to 1200 leas, the former cannot be put higher than 40 to 50 leas, and rarely even to that.

In the scutching operation, three several matters are obtained from the flax stems. The first is the fibre, which is the primary object, and which is the really valuable portion, that known as "flax" in commerce. The second is the woody refuse of the stems, hitherto applied to no other use than as fuel, or occasionally in Ireland as a covering for cuttings of potatoes, when planted, to protect them from frost. Mr. Pye, of Ipswich, however, proposes to make it available as an auxiliary food for cattle, having the authority of Professor Way that a sample analysed by him yielded 7·02 per cent. of oil and fatty matter; 7·93 of albuminous matter (containing 1·25 nitrogen), and 26·29 starch, gum, sugar, &c. He (Mr. Pye) recommended its use for feeding live stock, in conjunction with ground oats or other farinaceous food. Professor Hodges, nevertheless, in analysing another sample of this ground ligneous matter, gave quite a different result, his estimate of the nutritive constituents being as follows:—nitrogenised flesh-forming matters, 3·23 per cent; oil and fatty matters, 2·91; gum and soluble matters, 14·66; and he compared this with the average results of seven analyses of oil cake, giving nitrogenised matters, 28·47; fatty matters, 12·90; gum and other soluble matters, 39·01.

The third portion separated by the scutching process is termed "*scutching-tow*," in Ireland; in Russia and Prussia, "*codilla*;" in France and Belgium, "*etouppe de teillage*," described above. These branches of the trade consume annually many thousand tons, imported chiefly into Scotland, from Russia and Prussia. In France, Belgium, and Holland, the codilla or scutching tow is chiefly retained by the growers or factors at home, for a domestic manufacture of similar goods, and of coarse blouses and trowsers. It has also been employed for conversion, by Claussen's process, into a finely divided mass of fibres, capable of being mixed with wool and spun along with it into yarn, the fabric made from this yarn being chiefly hose.

Before proceeding to treat of the processes to which flax fibre is subjected subsequent to scutching, it may be well to glance at the uses to which the seed is applied. This valuable product of the plant furnishes two articles of much utility, and of very extensive use,—the oil and the cake. When the seed has been separated, dried and threshed out, it is either sold again for sowing or for conversion into cake and oil. Of course the former purpose only consumes a small proportion of the seed produced throughout the world, and in many countries it is not of a quality suitable to the chief flax-growing localities. Thus, while northern Russia, Germany, the Low Countries, and France either export seed for sowing, or consume their own produce to a considerable extent for this purpose; the southern provinces of Russia, the states along the Mediterranean, Egypt, Turkey, Greece, and the East Indies, while large exporters of seed for crushing, cannot sell any for sowing. The supply of the seed crushers of the United Kingdom is more largely obtained from Russia and Hindoostan than from any other countries. The entire annual import of seed into the British Islands averages 600,000 to 800,000 quarters, value between a million and a half and two millions sterling. The conversion of flax seed into oil and cake is carried out by different methods. In France, Belgium, Holland, and the north of Europe generally, where a large quantity is crushed, the apparatus employed is very simple and yet very effective. Lille, in France, Courtrai and Ghent, in Belgium, Neuss, in Prussia, and the province of Holstein are the great seats of this manufacture. See LINSEED.

The seed is pounded in a kind of wooden mortars, cut out of solid timber, and at the bottom lined with thick copper. By means of a revolving shaft, furnished with projecting notches of wood, beams of oak 20 feet high, the ends shod with

channelled iron, are alternately raised up and let fall into the mortars, where, in a short time, they convert the seed into a pulpy mass. When sufficiently pounded, this is then removed and put into woollen bags, which are then wrapped up in a leathern case lined with a hard twisted web of horse-hair, covering both sides and ends, but open at the edges. These are then ready to be pressed, and for this purpose are packed perpendicularly in an iron receptacle, narrow at the bottom, and widening towards the top. Packings of metal are then put in, and in the centre of the bags is inserted a beech wedge. A beam similar to that employed in pounding the seed is then set in motion, and at each descending stroke it drives the wedge in tighter, thus squeezing the bags of seed against the iron sides of the press. When the wedge has been driven home, another is introduced and battered by the beam, until it will drive no farther. At the bottom of the press are holes through which the oil thus pressed out of the seed runs into a receptacle beneath. In order to loosen the wedges and admit of the bags being removed from the press, a wedge of a different form, wide at bottom and narrow at top, and already a fixture in the press, but raised up and fastened by a rope during the driving of the other wedges, is released from the rope, and another beam drives it home, thus partially starting the differently constructed wedges and loosening the mass. The bags with the pressed seed are then taken out, and the latter, having lost the greater part of its oil while subjected to so considerable a pressure is found in a thin hardish cake, taking the form of the leathern case, and off it the woollen bag is readily stripped by the workman's hands. The oil obtained by this process is the purest and most limpid; but another process has to be performed before the seed yields all that the pressure is capable of extracting from it. The cakes, therefore, when taken out of the bags, are broken up and put into the mortar, where the same pounding operation takes place. When again brought into a comminuted state, the powder is put into a circular iron pan or kettle, under which is a fire, and slowly roasted in it, being kept from burning by means of an iron arm which is moved round inside by the machinery, constantly turning the ground seed. When sufficiently warmed by this operation, during which it is made to part more freely with the oil, the mass is again filled in bags and pressed as before, after which they are finally, the bags being stripped off, pared at the edges, put in a rack to dry, and stored for sale. The oil thus obtained is darker in colour than that by the cold process, and contains more mucilaginous matter. Many foreign oil-millers, however, only employ the hot plan, believing that they have thus a larger yield than when the cold pressure is first used. See LINSEED OIL.

In England, the cold pressure is little, if at all, practised, the seed being almost invariably warmed before pressure. The system of crushing, formerly universal here, had some resemblance to the Flemish method above detailed, the chief difference being in the mode of preparing the seed, prior to its being put in the press. The first process is to pass slowly from a hopper, the whole seeds into a pair of smooth or fluted metal rollers, which, in turning on each other, crack the seeds. Heavy edged stones then grind them into a meal, a little water being added during the operation, which facilitates the comminution of the seed. The meal is then put in the *kettle* before described, and while heated and stirred in it, the water mixed with it is evaporated. It is then bagged and put in the press, where the *stampers*, falling on the wedges, effect the desired results. The most recent improvement in the mode of pressure, and one now largely adopted, is the hydraulic press, and it is generally considered that a larger yield of oil can be obtained by its use than by the wedge and stamper-beam method. Blundell's (of Hull) patent is that most generally employed, and Messrs. Samuelson of that place are distinguished as makers of it, having introduced themselves some modifications and improvements. The oil obtained from flax-seeds or linseed, as it is generally termed, is of very extensive use in the arts, and is the chief vehicle for paints. To suit it for this purpose, and to make it dry quickly, it is mostly boiled in an iron pan, and during the operation a quantity of litharge is dissolved in it. The cake is a very favourite article with stock-feeders, being combined, as containing much nutriment in small bulk, with roots or other vegetable food, having large bulk with small nutriment. So extensively is it consumed in Great Britain, that besides the very large quantity made from imported seed, fully 80,000 tons of foreign cake are annually imported. On the continent inferior qualities of cake are ground to a coarse power, and either applied to the soil as a top-dressing, or steeped in a liquid manure, and the mass spread out on the land in that state.

Scutched flax fibre appears in the market made up in different ways. Russian is in large bales or bundles; Dutch and Flemish in bales weighing 2 cwt., the fibre being tied in "heads," each of which is about as much as the hand will grasp. Irish is made up in bundles termed "stones," the weight of which is either 16½ lbs. or 24½ lbs. In this state it is piled in the stores of the spinner, care being taken that it be placed

on a ground-floor, flagged or tiled, and not in a boarded loft, as the humid atmosphere of the former is conducive to the preservation of the suppleness and "spinning quality" of the fibre, whereas it deteriorates considerably when exposed to a drier air.

The first operation which it undergoes in the spinning factory is *hackling*.

This process is required to comb and straighten the fibres, to get rid of any knots, and to lessen and equalise the size of the filaments. The action of the hackles necessarily divides the scutched flax into two portions, the long, straight ones, which remain after the flax has passed through the operation, being termed "line," and the woolly or cottony looking mass which remains, being designated "tow." Both of these are spun, but the line produces the finer and better qualities of yarn, and is consequently much more valuable than the tow. The great object, therefore, is to obtain the largest possible quantity of the former from a given weight of scutched flax, and the yield of line varies considerably according to the nature of the season. Spinners, therefore, are anxious as each new crop of flax is brought to a marketable state, to test the yield of line, so as to guide them in their purchases. They are thus enabled to ascertain more clearly the suitability of the samples for "warp" or "weft" yarns, and for thread-twisting. Warp-yarns being those which constitute the long threads of a linen fabric, require to be harder and stronger than weft-yarns, which form the cross or short threads.

The yield of line, as well as the general economy of the operation, is, of course, greatly dependent on the nature of the hackling-machine employed, and great scope for care and ingenuity is thus given to the machine makers. A great number of hackling-machines have, from time to time, been brought out, employed in the factories, and subsequently abandoned, when others, having greater merit, have been invented.

In the early period of the linen manufacture, when spinning was done exclusively by hand, no hackling-machines were employed. The process was exclusively effected by hand-hackles. Even after the introduction of machine-spinning, they were, for a long period, the sole means of hackling. Of late years, the machine has been more and more brought into use, and although hand-hackling still exists to a considerable extent, the other method is by far the more extensively employed.

For hand-hackling, the tools used consist of a surface studded more or less thickly with metal points, called hackle-teeth, through which teeth the flax is drawn by the operator.

The hackles ordinarily used for hand-hackling in this country are in the form of rectangular parallelograms, presenting a line of 7 inches towards the worker, and 4 to 5 inches deep. The first tool employed is called the "ruffer," the pins of which are about ¼ inch square at their base, and 7 inches long, and brought to a fine point; the second is the "common 8," which is always used after the "ruffer;" then the "fine 8," the "10," the "12," the "18." The pins of all these tools are similarly placed to those of the ruffer, but are somewhat shorter in length, and are more slender as the tools increase in fineness. In all these tools the pins are held in wooden stocks of about ⅜ inch in thickness and covered with sheet tin. This sheet tin, through which the pins are driven, helps to support them and prevent the wood from splitting. These tin covered stocks are only of a size necessary for the extent of pins employed, and are themselves screwed to other larger pieces of board, a little broader and some inches longer than themselves, and by which they are ultimately fixed to the hackler's bench, inclining somewhat backward with their points from the worker, and a sloping board behind to prevent the flax entering too much in the pins, thus:

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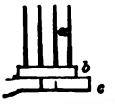

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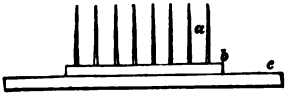

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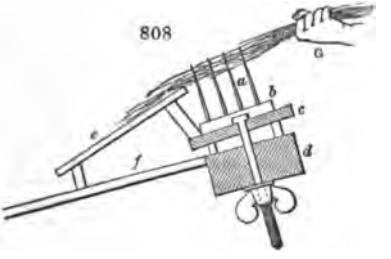

Fig. 806, end view of a hackle; *fig.* 807, front view of hackle; *fig.* 808, hackle, &c., fixed up for working. *a* pins; *b* tin covered stock; *c* foundation board; *d* beam of table or bench; *e* back board; *f* table to receive the tow, &c.; a hand of workman. Such is

the form of hackle used in England, and also the manner they are, of whatever description, fixed for work.

The operation of manual hackling is simple in principle, although it requires much experience to acquire dexterity.

The workman having first divided the flax into handfuls or stricks, of which there are 300 to 400 to the cwt., proceeds to grasp one as flatly spread as possible between his forefinger and thumb, by about its middle, and wind the top end round his hand in order the better to prevent the slipping of the fibres; he then begins by a circular swing of his arm to lash the root end into the hackle, taking care to commence as near the extremity as possible, now and then collecting the fibres by holding his left hand in front of the tool, turning the strick from time to time. He thus gradually works up as near as possible to his right hand, when he seizes the ruffed part of the strick and holds it in the same manner as at first, and proceeds by a similar treatment to "ruff" the top end; when this is finished the "ruffed" work is taken to the tool called a "common 8," the pins of which are much closer placed than those of the ruffer, and are only four or five inches long. This "8" is always used after the ruffer, but from it the work can be taken to any of the finer tools, viz. 8, 10, 12, and sometimes 18. It is usual and better to dress both ends over each tool before taking the work to the next. The pins of all these tools are 4 inches long, in order, as was supposed, to have sufficient spring. The flax is not lashed into them as into the ruffers, neither are the ends required to be wound round the hand. But the root end of the flax is always the one to be first worked, and the hackling begun at nearly the extremity of the stick, which on being drawn through the hackle is received by the left hand of the workman, and by it carried back and laid upon the back board and over the point of the pins, for the angle of inclination of the hackles and a slight lowering of the right hand causes it to enter sufficiently on being drawn forward. As it is impossible to ruff or dress entirely up to the hand, when the hold is changed in either operation, there must of necessity be left a certain space to be repassed through the tools; this is called the "shift," but the less length that is required for this purpose the better for the yield of line. The numerous long fibres that slip from the strick in ruffing must be collected and drawn from the mass of tow attached to them, when they can be relaid in the strick, or kept to be dressed separately under the name of "shorts," and from time to time the short fibres or tow sticking to the teeth of the finer tools are removed. Whenever one-half of the length of the strake of flax is hackled, it is turned round to hackle the other half. This process repeated upon each hackle. From 100 pounds of well-cleaned flax, about 45 or 50 pounds of hackled line may be obtained by the hand labour of 12 hours; the rest being tow, with a small waste in woody particles of dust. The process is continued, till by careful handling little more tow is formed.

To aid the hackle in splitting the filaments, three methods have been had recourse to; beating, brushing, and boiling with soap-water, or an alkaline lye.

Beating flax either after it is completely hackled, or between the first and second hackling, is practised in Bohemia and Silesia. Each hackled tress of flax is folded in the middle, twisted once round, its ends being wound about with flaxen threads; and this head, as it is called, is then beaten by a wooden mallet upon a block and repeatedly turned round till it has become hot. It is next loosened out, and rubbed well between the hands. The brushing is no less a very proper operation for parting the flax into fine filaments, softening and strengthening it without risk of tearing the fibres. This process requires in tools, merely a stiff brush made of swines' bristles, and a smooth board, 3 feet long and 1 foot broad, in which a wooden pin is made fast. The end of the flax is twisted two or three times round this pin to hold it, and then brushed through its whole length. Well hackled flax suffers no loss in this operation; unhackled, only a little tow; which is of no consequence, as the waste is thereby diminished in the following process. A cylindrical brush turned by machinery might be employed here to advantage. These have been tried in establishments for machine spinning, but not found advantageous.

The object of all hackling being to produce a good yield of line with tow of good quality, that is to say, free from broken, unsplit fibres, lumps, and knots; the care and attention necessary to do this, with the expense and uncertain result of the individual skill of workmen, urged manufacturers to attempt the establishment of machines for effecting the process. Therefore many contrivances were invented with this view, but it was long doubted whether any of them made such good work, with so little loss, as hand labour. In hackling by the hand it was supposed that the operator would feel at once the degree of resistance, and be able to accommodate the traction to it, or throw the flax more or less deeply among the teeth, according to circumstances, and draw it with suitable force and velocity. For a considerable period these ideas, or rather prejudices, as they may now be called, seemed to be confirmed; for the earlier

attempts to supersede hand hackling, like those in many other undertakings, though partially favourable, were, on the whole, rather discouraging. In attaining one point desired another was lost, for too much still depended on the care and attention, if not on the actual skill, of the persons attending the machines.

It will be desirable, therefore, to give particulars respecting some of those which have been from time to time invented, although they are not now in use, as a lesson for preventing the repetition of things already known, as well as to illustrate the steps successively taken. The first machine invented, or, at least, published, was called the "Peter," and was intended to illustrate, as clearly as possible, the movements of the hand hackler. The flax was first divided into small convenient portions or handfuls, about 4 oz. each, called "stricks," which, before being taken to the machine, were slightly straightened and dressed over the ordinary hand "rougher." Each of these was then placed between a pair of short iron bars, called a "holder," one of which had an indentation in the middle, and the other a corresponding projection. Thus, when tightened together by screws 4½ inches apart (such length being equal to a man's grasp), the strick of flax was firmly held while exposed to the action of the hackles. The holder was then suspended from movable levers over a truncated rectangular cylinder, upon the angles of which were fixed, at a certain angle, hackles similar to those used in the manual operation. The levers supporting the holders received from a crank a short up and down motion, so timed in their oscillations as to strike the holder nearly against the points of the pins at the time they were passing under, coming thus as nearly as possible to the effect of a man striking in and drawing through the hackles, except that the flax remained nearly stationary, and the hackle was drawn through it by the rotation of the cylinder, whereas in the hand process the hackle was stationary, and the flax drawn through it by the operator. Each machine carried two holders. The tow made and collected from the holders was seized and taken off by boys stationed for that purpose, while another, at the ringing of a bell, took out and changed the sides of the stricks to be presented to the action of the hackles, and subsequently withdrew them from the first machine to another similar but with finer hackles, and thus continued until the root end—always the first operated on—was dressed to the desired degree of fineness, when they would be taken to a table where another set of boys, previously to removing the first holder, put on a second to the already hackled part, leaving about 2½ to 3 inches to be re-hackled. This operation is termed "shifting," and the space left, "the shift;" it is thus performed and remains so called at the present day, the only change being that in the holder now in use one screw is used for two stricks instead of two screws for one strick.

Fig. 809 will more clearly show the construction of this machine. A, square truncated cylinder carrying the hackles; B, oscillating arm or lever for supporting the holder; C C C, framing; D, crank and shaft; E, connecting rod from crank to oscillating arm; F F F F, hackles; G G G G, back board; H, holder. The first motion was given by pulleys on the shaft D, which revolved 4 times to 1 of the hackle cylinder, by the intervention of suitable wheels. The worm and wheels for the bell motion were attached in the usual manner to the shaft of the cylinder.

Machines of this construction continued in rather limited use without any change or competition till about the year 1825, when a patent was taken for a machine known as the pendulum machine. The flax in the holder being suspended and swung backwards and forwards while the hackle remained fixed, the flax was thus hackled, stroke for stroke, on each of its sides. The boys, as in the last described, snatching off the tow as it was formed, and at certain times, that is at each rise of the pendulum, for it had a rising and falling motion to imitate the hand workers in commencing at the extreme end of the flax, passing the holder from one recess to another of the pendulous table, so as to arrive at the progressively finer tools when ranged along the machine; but sometimes the different tools were fixed upon the angles of a square cylinder that presented a finer range, the whole length of the machine, by turning up a new angle at each rise of the pendulum, when the labour of the boys was simply to put in the tow and take out from it the flax. The adjoining diagram (*fig.* 810), without entering

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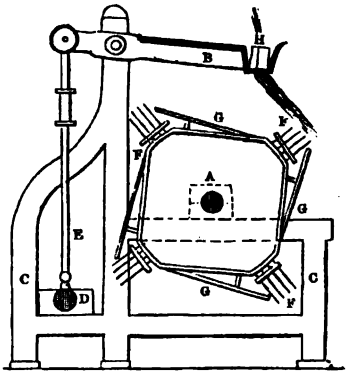

on any details of a machine that was so little used, will make the theory of its action quite clear

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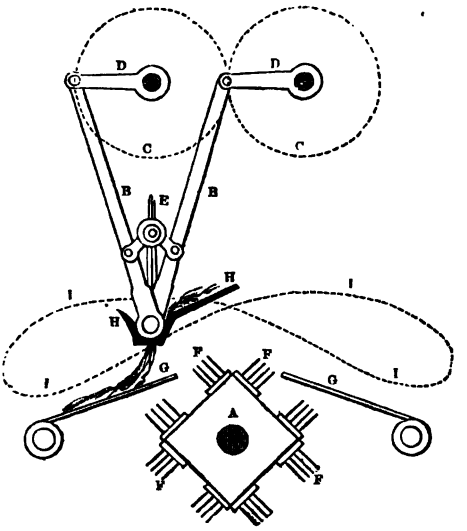

A, hackle bench sometimes revolving so as to present different degrees of hackles at its various angles, sometimes stationary with the gradations of hackles upon its length; B B, pendulum arms; C C, equal wheels working into each other; D D, crank arms; E, radial slide-bars to preserve the holder table vertical; H, holder table; F F F F, hackles; G G, back boards; I I, direction in which the holders swing; there were the same wheels, &c., at each end of the machine, and the holder table H reached from one to the other. The wheels, C C, with all attached to them, were made to rise and lower upon the hackles, and the backboards G to rise when the hackle bench turned.

About the same time another patent was taken out for a machine, where the holders were suspended above one end of a travelling sheet of hackles. This machine also required hand labour to turn and transfer the stricks, though the tow was caused to fall clear from the hackles by mechanical means. The following sketch (*fig.* 811) shows the principle upon which this machine works, and though never much employed at the time of its appearance, has subsequently served as a foundation for those that are now in the zenith of their prosperity.

A A (*fig.* 811), sheet of hackles; B, support for holders; C C, carrier pulleys for the sheet of hackles. *Fig.* 812, a larger view of the hackle bar G G, in order better to show the faller D D D, in the staples or grooves E E, and *fig.* 813, at the end of the hackle-bar G G; F F, pins of the hackles, between the rows of which the faller D D D acts to push the tow off the pins. There is a clearing faller D to each hackle, which is kept to the bottom of the hackles at that part of their course where they are in contact with the flax, but at the turn F D fly beyond the points, as shown by the effect of the centrifugal force.

All these machines, possessing great similarity of features in regard to the personal attention required, never came into such general operation as to supersede entirely hand-dressing, either from their own defects or prejudices against their employment. About the year 1830, in consequence of the new mode of spinning being carried on with considerable energy, it was found advantageous to cut the flax into 2, 3, or more lengths previously to hackling, which rendered it necessary to have machines peculiarly adapted for this new short description of material. This machine, known as the excentric or circular machine, deserves considerable attention for its own inherent merits, and the extensive utility it has proved to be of in suggesting the principal parts of those by which it has been supplanted. In its original form it was made of a breadth suitable for only one strick, and consisted of a

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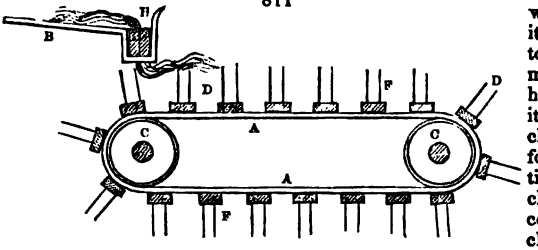

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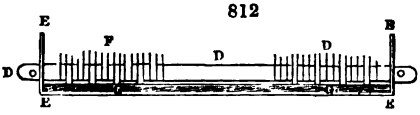

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cylinder 3 ft. diameter, upon the whole circumference of which at intervals of 3 or 4 inches were fixed the hackles. As each machine could only carry one description of hackle, it was necessary to employ a series of these machines, called a "class," when the flax required to be dressed over a succession of finer tools, each succeeding machine carrying a finer tool than its predecessor. The hackles were cleared of tow by coming in contact at one part of their revolution with a brush roller, which also revolved in contact with a cylinder covered with card clothing, the points of the pins being in such a direction as to clear the brush from tow, and allow itself to be in its turn cleared by the oscillations of a comb, whence by rollers the tow was brought into a sliver. In order to preserve the continuity in the supply of tow, and maintain the regularity of the sliver produced by it, the holders with the flax were presented to the hackle cylinder in a manner peculiar to this machine, and in endless succession by means of certain circular carriers placed at each end of the hackle cylinder, but excentric thereto, and at such a distance apart as each should bear one end of the holder as it extended across the cylinder parallel to its axis. Thus, the holders introduced at that part of the circumference of these carriers furthest from the hackles were carried forward, while the flax was in operation, till they were brought almost into contact with the points of the pins, when, by the intervention of a slide, they were withdrawn from

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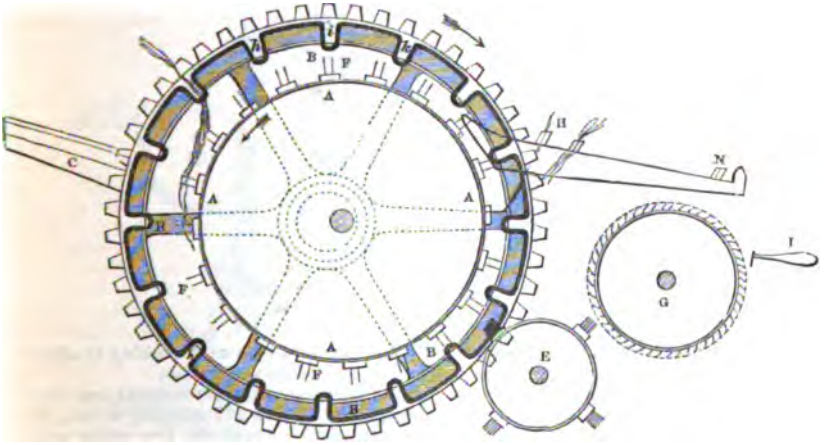


the machine, but with one side only of the flax dressed, and that but on one tool; therefore the holder required replacing in the same machine, in order that the second side of the strick should be dressed as was the first. The holders then required to be carried by hand to each succeeding machine of the class.

The preceding figure (814) shows the leading features of these machines: A A, hackle cylinder; B B, excentric wheel to carry holders in its recesses *h*, *h*, *h*, *h*, *h*; C, slide upon which the holders were laid so as to fall into the recesses *h h* of wheel B; D, slide for taking out holders; E, brush cylinders with brushes; G, cylinder covered with card clothing; H, holder come out; I, doffing comb. The space of the holder carrying wheel was filled with holders, and so maintained in endless succession, and thus each served in some measure to keep the end of its preceding one down into the hackles.

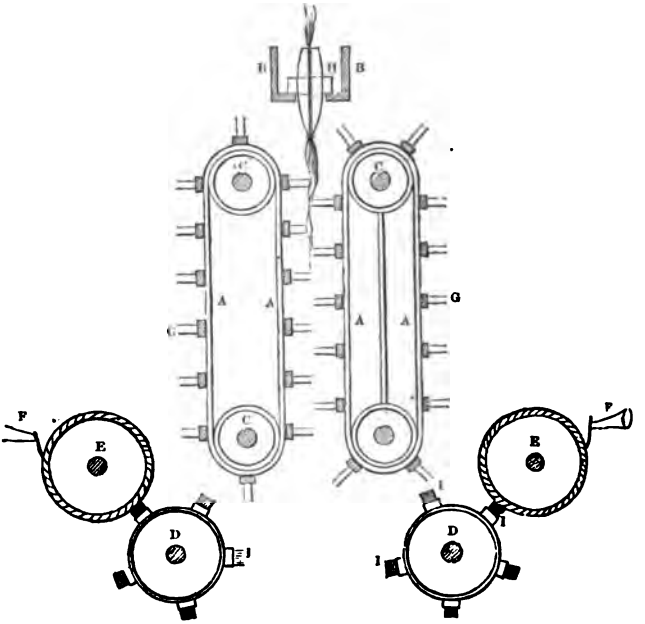
About 1833, a machine was patented consisting of two parallel cylinders, over which the flax was carried, revolving in its progress so as to present the alternate sides of the strick to the hackles, the progressively finer tools being ranged along these cylinders, so that having passed the length of one cylinder one end was completely finished. When the holder was taken out, "shifted," and replaced, it was carried back along the second cylinder, and thus returned to where it commenced, finished. This machine, however, never was carried further than the experimental one for the patent.

Another machine (Wordsworth's) the same year made its appearance, and which for some time enjoyed much celebrity. It consisted of two parallel vertical sheets of hackles running together, and so geared that the hackles of one intersected the interstices of the other. The flax suspended in its holder from a species of trough passed between these two sheets, and was thus hackled simultaneously on each side in

its course through the progressively finer hackles from one end of the machine to the other.

A A (815), hackle sheets; B B, holder trough or slide; C C C C, pulleys for carrying

815



the hackle sheets; D D, brush rollers; E E, rollers covered with card clothing to clear the brushes; F F, doffer combs; G G G G, hackles; H, holder; I I, brushes.

It is unnecessary to notice more at length the different machines brought out, employed for a time, and then rejected. Although the hackling and spinning of flax, in the full length as it grows, was what was first practised by hand, the first really successful machine for hackling was what was known as the "circular machine" for hackling "cut line," as it is called, or the long flax fibre broken into several lengths. It had always been known that the top and root ends of the fibre were of very inferior quality to the middle, and of course when all was spun in one length the yarn produced was inferior to what the middles could be spun to, while superior to what the tops and roots would produce. It therefore occurred that in the general qualities of flax the division of the fibre, so as to separate the different portions named, would be advantageous to the spinner. The operation of cutting was performed by a simple machine consisting of a pair of jaws, so constructed that when the flax is introduced between them the different parts, instead of being clearly cut off, are, so to speak, bitten off, leaving ragged ends. This is desirable in order that the ragged ends might interlace in the spreading prior to going through the preparing machines, which precede the spinning operation. The machine for hackling cut line was brought out about thirty years since, and underwent, before it was finally set aside, a considerable number of modifications for the purpose of economising the labour in working it. About the same time the "flat machine" was introduced, which was more particularly intended for hackling long flax. The nature of the operation of these machines was the same, the flax being acted on by different series of hackles fixed in the circumference of a cylinder in the one machine, and on an endless sheet in the other. The curvature of the cylinder was no objection in hackling cut flax, but for acting on long fibres it was necessary to put the hackles on a sheet, for the purpose of getting sufficient length of flat surface. The most successful machines, and which displaced all previous ones, have been modifications of these of different kinds, some of them being simply contrivances for saving manual labour, and giving certainty to the action, and others combining other improvements with this object. Carmichael's patent machine (*figs.* 816, 817) was, as brought out at first, simply the old flat machine with self-

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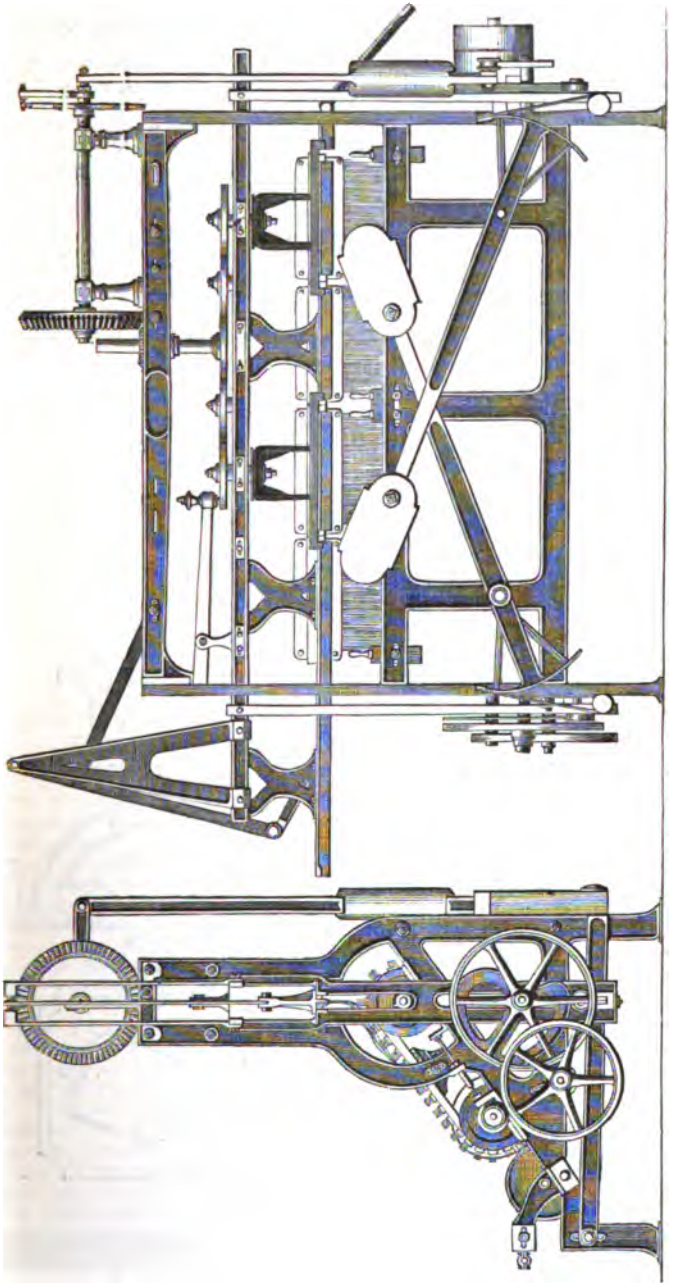

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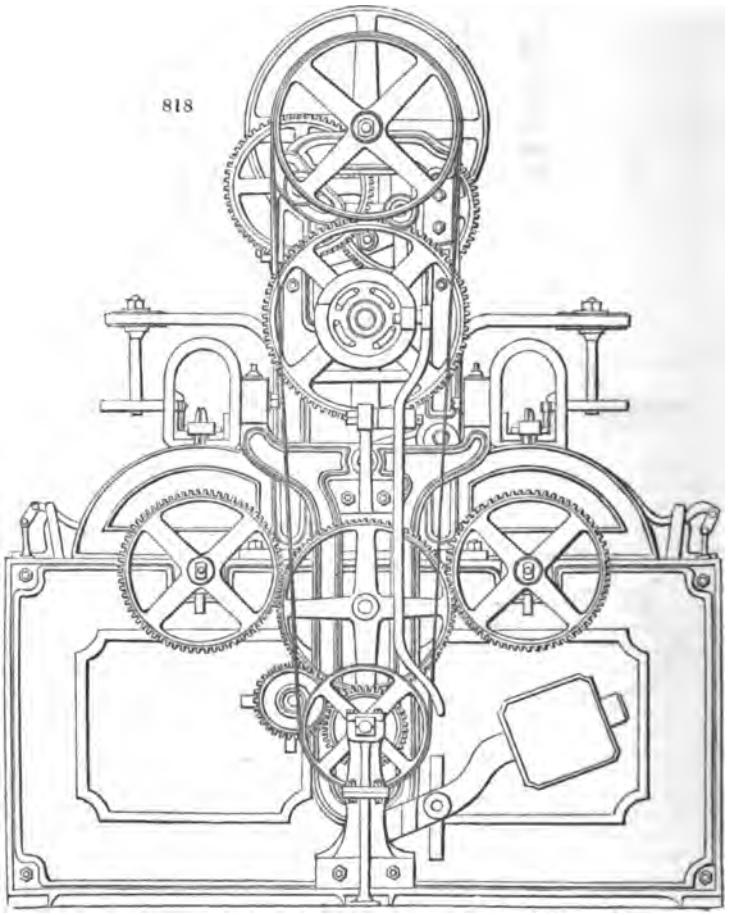
acting motions for actuating the holders applied to it. It was afterwards much improved by the adoption of an inclined sheet in imitation of a very successful self-acting modification of the old flat machine which was brought out by Combe, of Belfast, whose machine, at this time, is considered by many to be the best one in use for long line.

The distinguishing feature in these rival machines is, that in Carmichael's the motions are all performed by the descent of ponderous weights, while in the other they are performed by the direct action of the machine.

There are other differences affecting the working of the machines, which are by practical hacklers considered of great importance, and as giving more value to Combe's machine. The most important of these is the facility of adjusting the place where the holders approach the flax, which greatly affects the yield of line.

The same principles of actuating the holders were applied to cylinder machines for hackling cut flax, but as these have been displaced by more recent inventions, it is not necessary further to refer to them. Wordsworth's machine, already figured (815), was of importance, as being the basis of several other valuable machines. Its essential feature was arranging the hackles on two sets of endless sheets placed opposite each other, and driven and connected by wheel-work so as to revolve together, the surfaces being placed so close together, that the hackle pins penetrated the flax from both



sides, and hackled at the same time. The large circle described by the points of the hackles in this machine, which prevented them cutting the flax close to the holders, and other imperfections, led to its abandonment. About sixteen years since, Combe

of Belfast, designed for the eminent flax-spinning firm of Marshall and Co., of Leeds, a modification of this machine, which since has been known as Ardill and Pickard's machine, and has come into extensive use. The principal new feature in this machine was the introduction of cranked wheels for supporting and carrying the hackles, for the purpose of making the points of the hackles describe a small circle, and thus enable them to cut close to the holders. Although successful, this invention did not fully accomplish the object aimed at. About the same time, Marsden's intersecting machine was brought forward, and possessed a great reputation for a length of time. Its success was a good deal owing to the flax hackled by it having an apparent fineness, but this was not found to be of practical value, as the spinning quality was not improved thereby. For this reason it has gone greatly out of use.

The next machine which came into extensive use was Combe's reversing cylinders, *fig.* 818. These machines are constructed in a great variety of forms for different kinds of work, and seem to give very good results. They are simple in their construction, and give little trouble, acting lightly on the flax and making very wiry fibres. They are made of all sizes, from 12 to 30 inches in diameter, and with 4, 6, or 8 graduations of hackles, according to the kind of work to be done on them. The flax is hackled on each side, or each graduation of hackles, by reversing the direction of the rotation of cylinders. The tow, or short fibre, is thrown off the hackles by stripper rods, placed between the rows of pins.

The next machine to be named is by the same inventor, and is styled the patent reversing sheet hackling machine. It is for long line, on the same principle as that just described, except that it has the hackles fixed on flat sheets, as in the "old flat" machine. It is simple and complete; easily driven and attended, and a considerable number are now in use. From the hackles being on a flat sheet, it is necessary to make the holders descend, first on one side while the sheets are moving in one direction, and then on the other while they are moving the other way. This is done by supporting the channels which carry the holders on four levers fixed on two oscillating shafts, to which motion is communicated by a shaft. The holders are slid through by a lever on the top, which acts on a sliding bar, by means of a ball, which forms a universal joint and actuates the holders, whatever position the channels are in. The drawing here given, *fig.* 819, will show the mechanism.

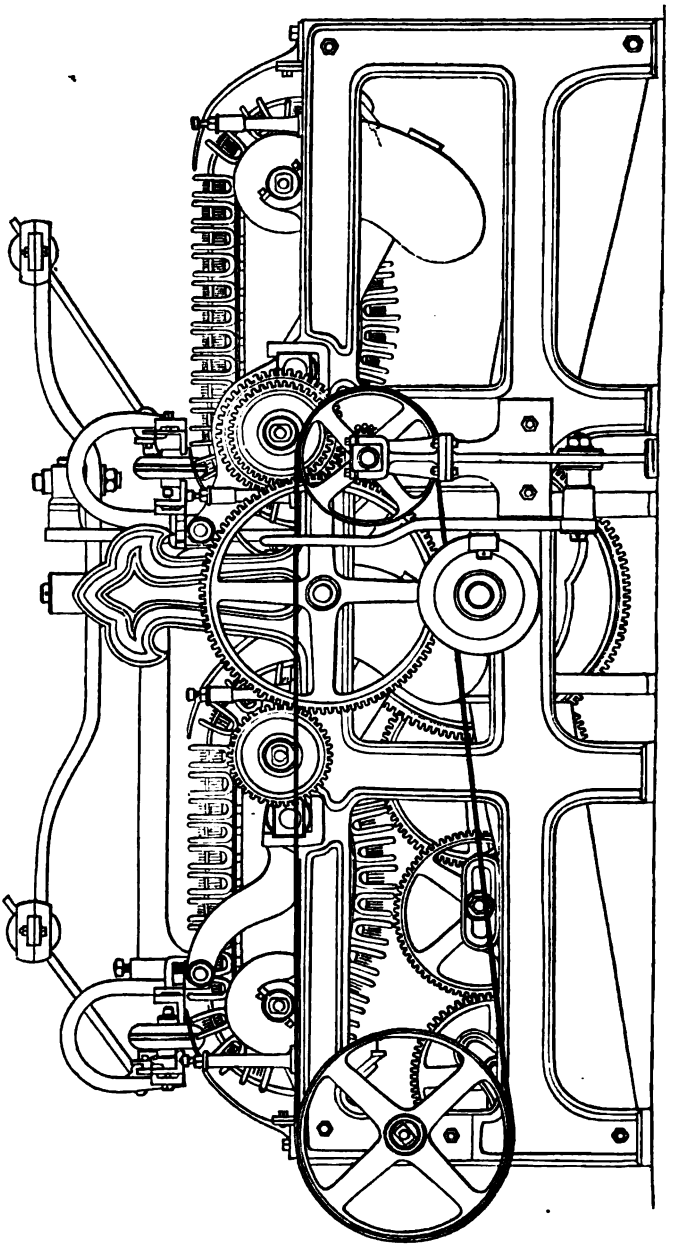
Both the machines last described are made double, or in fact, the construction of each is that of two machines in one. The table for filling and changing the flax in the holders is attached to the machine. One side hackles one end of the flax, and the other side the other end.

We now have to describe a machine for hackling cut line, patented by Mr. Lowry, of Manchester, and now extensively in use at home and on the continent. It is virtually a modification of Wordsworth's machine, already described.

Fig. 820 is a side elevation of a sheet hackling machine to which these improvements are applied; *fig.* 821 is an end elevation of the same; *fig.* 822 is a front view; and *fig.* 823 an end view of one of Lowry's improved hackle bars. In *figs.* 820 and 821, *a a* represent the belts, sheets, or chains to which the hackle bars *b* are attached. These belts, sheets, or chains pass around the small drums *c c*, and larger drums *d d*, which are turned round by the gearing, shown in the drawing, or by any other suitable arrangement of gearing. The hackle bars *b*, are made with a recess to receive the stock of the hackles *e*.

The hackle bars *b* are connected to the belts, sheets, or chains *a*, *a*, by means of rivets or screws, passing through the flanges *b*, and through the belts, sheets, or chains *a*; and at each end of each hackle bar is a stud or guide pin b^2, which, when the hackles arrive near the small drums *c*, *c*, take into the groove in the guide plates. The object of these guide plates is to support the hackle bars in passing over the small rollers *c*, and during the operation of striking into the strick of flax or other fibrous material to be operated upon. The holders with the stricks depending from them, are placed within the rails *i*, *i*, and these rails are made to rise and fall and the holders are made to pass from one end of the machine to the other, in the usual manner. When the machine is at work the drums *c* and *d* revolve in the direction of the arrows in *fig.* 821, and the hackle bars being attached to the belts, sheets or chains *a*, and supported by the guide plates, cause the hackles to enter the stricks of fibrous material at or nearly at right angles to the fibres thereof, and to retain that position at the commencement of their downward motion; whereby as the belts, sheets, or chains continue to descend, the hackles are drawn through the fibrous material for the purpose of removing the short fibres and extraneous matter. Another great advantage resulting from this improved mode of attaching the hackle bars *b* to the belts, sheets, or chains *a*, is, that the hackles can be made to enter the fibrous material at a point closer to the holder than in any of the sheet machines now in use. When the hackles are passing round the drums *d d*, they are cleansed by the

revolving brushes *j j*, which deposit the material removed from the hackles on to the card drums *k, k*. These drums are cleansed or doffed by the combs *l l*, or in any other convenient manner.



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This machine is also used to a very large extent, and well liked for dressing half line and full length flax. For this purpose the sheets require to be made six inches

longer from centre to centre, and the head or trough to lift 3 inches higher, and the top rollers to approach and recede from each other simultaneously with the rising and falling of the head.

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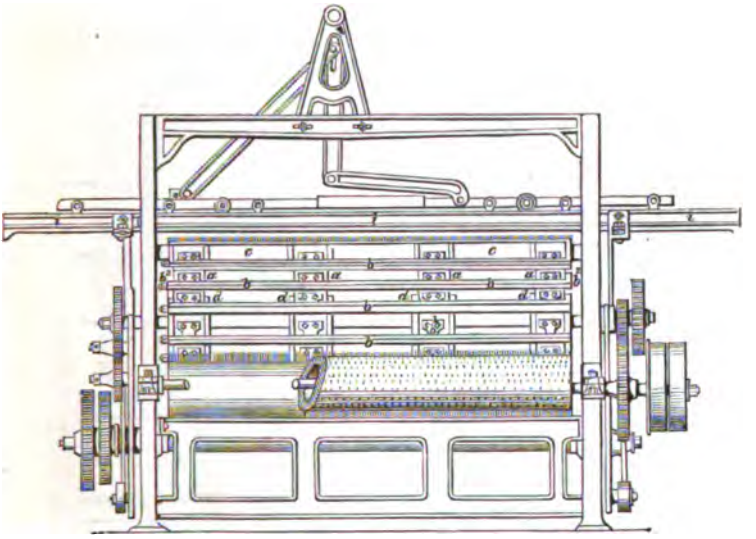

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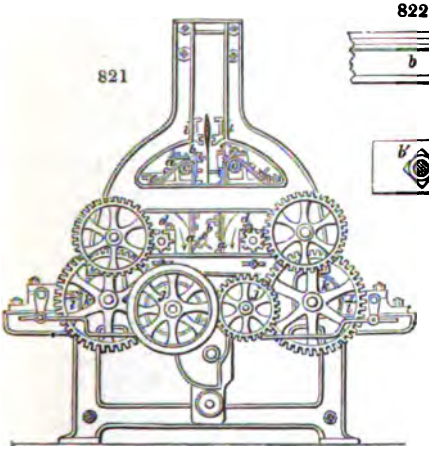

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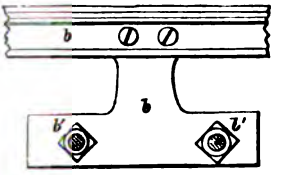

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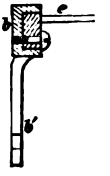


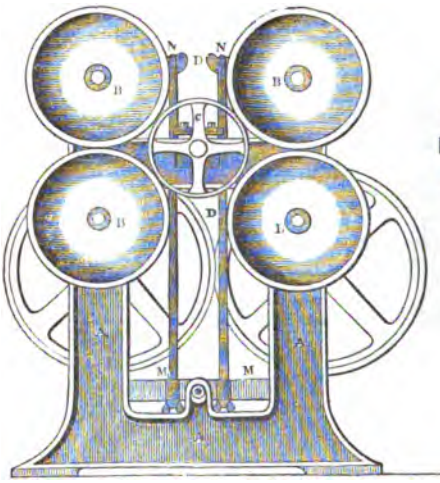
Combe, of Belfast, has recently produced another edition of Wordsworth's machine. Its novel feature consists in dispensing with bars altogether, in carrying the hackles and in fixing them directly on the leather sheets. By this means a very true action is obtained, and the working parts are so light, that the machine bears any speed with scarcely any wear and tear. In this invention there is also combined convenient modes of regulating the lift and severity of the cutters to suit different kinds of flax, and the holders are carried through the machine by a separate apparatus for that purpose, while they are at their highest elevation, instead of during the whole process of lifting, as had always been the case in other machines.

The cutting of flax already referred to, is effected by a machine consisting of a species of circular saw about 20 in. in diameter; but, instead of a single blade, it is constructed of 3 or 4 plates of steel, each about ¼ in. thick, and having angular projections from their circumference. This revolves at a considerable velocity, while the flax, firmly grasped in each hand by its ends, is still further held and slowly

carried against the saw by two pair of grooved pulleys pressed together by a considerable weight. It is thus partly sawn and partly broken through. Flax may be cut into 2, 3, and sometimes 4 divisions: and sometimes the dead harsh fibres that are frequently found at each of its ends only are cut off and used as tow; but more generally the different portions are hackled and used for the purposes they are sorted for.

Description of flax cutting machine (*figs.* 824, 825). A A, framing; B, the grooved

824



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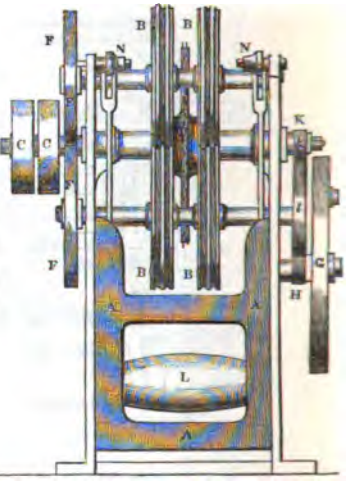


pulleys for holding and carrying the flax; C C, the driving pulley; D, saw or cutter; E, F, wheels for gearing together the pair of holding pulleys; G, H, I, K, pinions and wheels for producing the proper relative speeds between the cutter and pulleys; L, weight, which by levers M and N, causes the pressure of the holding pulleys.

Preparing. — By this term is understood those preliminary operations through which both line and tow must pass after the hackling and before the spinning process.

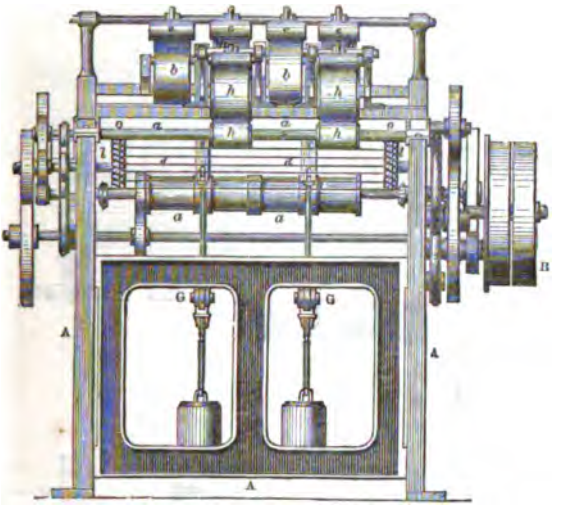
The mechanism and modes of proceeding for this purpose which consist of repeated drawings, are similar for "long" line or "cut;" though the dimensions and fineness of the machinery must be made suitable for their various lengths and qualities. But in the preparation of tow a peculiar additional operation is demanded, as a consequence of the different state of the fibres of which the material is composed; this operation, termed "carding," has for object to bring the highly irregular and entangled mass into a somewhat more homogeneous and uniform state, previously to its being afterwards drawn and equalised in a manner similar to line.

In the preparation of line the first operation is called "spreading," or first drawing; and the machine employed a "spreader:" those subsequently are the second and third "drawings" (sometimes a fourth is used), and lastly the "roving." It is upon the spreader that the separate stricks of line are first combined and drawn into long uniform bands or ribbons, called "slivers," of determinate lengths. This is effected by subdividing the stricks into two or three portions, and then placing them consecutively, slightly elongated, and overlaying each other about ⅓ths of their length upon and in the direction of an endless creeping sheet or apron. The machines are generally made with two of these creeping sheets or aprons, and upon each sheet are thus laid two distinct lines of stricks; each of which forms a thick uniform body of line, and capable of being maintained to an indefinite length. These endless creeping sheets supply continuously another part of the machine, where the body of "line" is drawn out to between 20 and 60 times its original length, according to whether it is composed of cut or long flax. This part of the machine comprises a pair of holding or back rollers; an endless succession of bars called fallers, bearing combs of closely ranged steel pins, through which the slivers are drawn; a pair of drawing rollers; an arrangement of diagonal or doubling bars; and a pair of delivering rollers. Is generally termed the "gill frame," or "gill head," probably from the French word "aiguilles" (needles), as descriptive of the combs, and to distinguish this machine from

those formerly used for the same purpose, which simply consisted of a series of rollers, under and over which the line was passed.

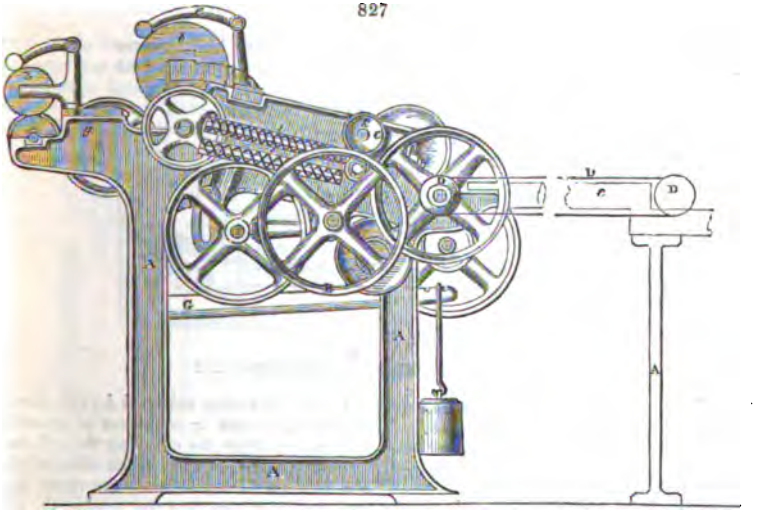
The following figures, 826, 827, show the outline of the present most approved gill spreader or first drawing.

826



A A, general frame of the machine; B, driving pulleys; C, auxiliary frame for endless sheets; D D D D, rollers for carrying the endless sheets or aprons; E E, con-

827

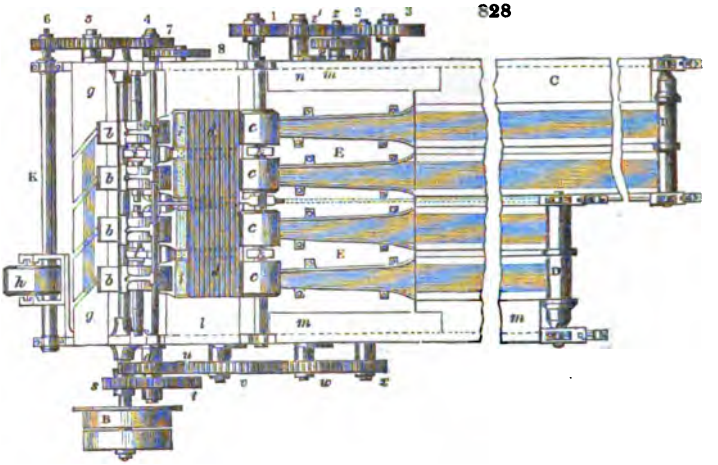


ductors to guide and slightly condense the four bodies or slivers of line; F, can for receiving the sliver; G, lever for weight on front or drawing roller; H, lever for weight on back roller; K, delivering roller shaft, spring, and bell, which, by the intervention of gearing between it and the front roller, is caused to ring when any desired length of sliver is delivered.

a a, the iron drawing roller or boss; *b b b*, the wooden or pressing roller, by the pressure of which upon *a a* the sliver is held during the greater velocity of these rollers over that of *c*; the holding or back rollers elongate in exact proportion of its aug-

mentation; the holding roller *c* is in like manner pressed against another in order to assist the "gills" in retaining the fibres; *k k*, hooked rods to connect the weighted lever *h* with the holding roller *c*, and by the pressure thus caused insure its effect;

828



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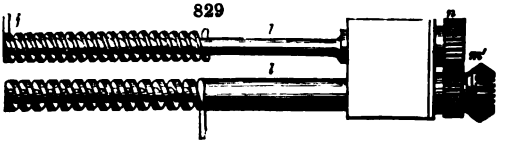
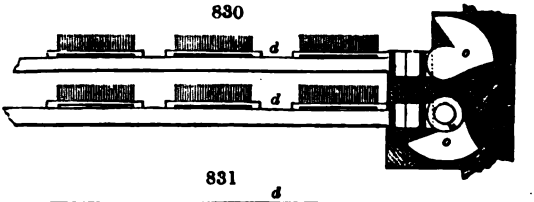


d the sheet or surface of "gills" composed of separate bars, as seen at *fig.* 830, 831; *e*, rubber or cleaner of pressing roller *b*; *f f*, conductors to contract laterally the sliver at the moment of drawing; *g*, plate of metal having diagonal openings at an angle of 45° (this plate is sometimes called the "doubling bars," having been first made of separate bars) to the original course of the sliver, in order to enable it to be

830



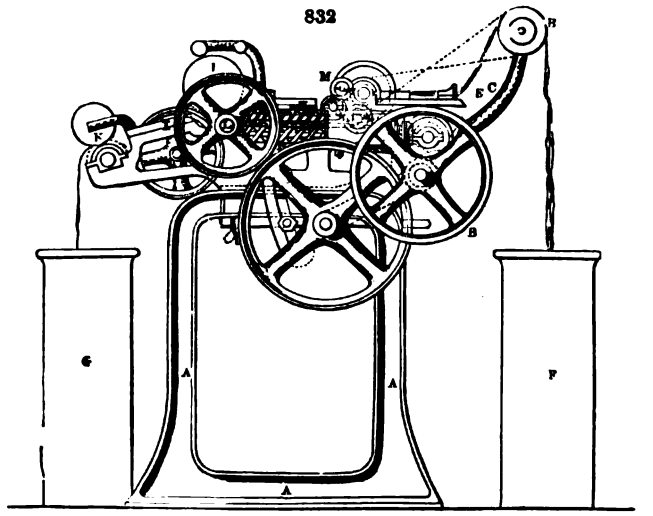
831

turned in a rectangular direction and guided to the delivering rollers *h h*; this direction of the sliver is more distinctly seen at *fig.* 833; *i*, hanger or connector of pressing roller *b* to its weight lever *c*; *l l*, the screws or worm shaft for carrying the gill bar *d d*; *m m*, the shaft with bevel wheels by which the screws at opposite sides of the frame are caused to move simultaneously; *n n*, pinions for connecting the upper and lower spirals of each pair; *o o*, the cams or excentrics for lowering and raising the gill bars; *p p*, weighted guide lever or bell cranks for guiding the faller in its descent, and moderating the shock caused by its weight when coming in contact with the lower slide or support; *q* and *r*, worm and wheel for bell motion; *s*, *t*, *u*, *v*, *w*, *x*, line of wheels from pulley to front roller and from front roller to back; 1, 2, 3, line of gearing from back roller to sheet; 4, 5, 6, 7, line of gearing from roller to delivering roller; 8, from roller to brush; *y y*, from back shaft to back roller.

The machines for the second, third, and fourth drawings, though in principle essentially the same, yet differ in some of their minor details from the foregoing, as

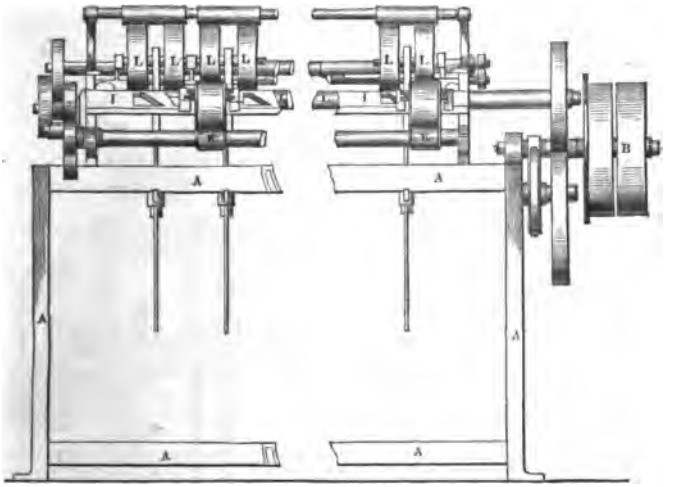
they do not require the feeding sheet to supply them, the "sliver," from the spreader having sufficient coherence as to allow itself to be drawn from the cans direct by the back rollers of these machines; neither is a bell motion requisite to determine the length of slivers produced by them. The subjoined sketches show the general parts requisite (*figs.* 832, 833).

832



A A (*figs.* 832, 833), framing; B, driving pulley; C, support of sliver carrier; D, roller for carrying sliver; E, conductors; F, can containing the slivers from the first drawing; G, receiving can; H H, the hackle carrying spirals; I, the diagonal or doubling bars; K, delivering rollers; L, the drawing rollers; *m*, *m*, *m*, the retaining rollers.

833

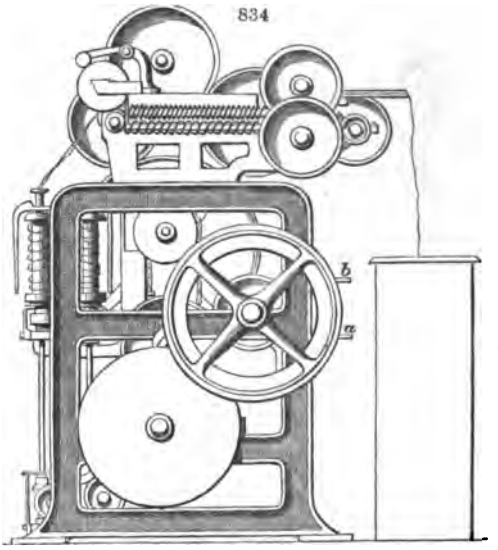


The roving frame is the same in regard to the arrangement of its back and front rollers and gills, as the drawing frames; and as the position and manner of regulating the poles are generally the same as adopted for cotton, the description of these parts therefore does not require to be repeated; but an improvement patented a few years since by Sir P. Fairbairn, of Leeds, of that part of these frames which relates to

regulating the taking up movement of the bobbin merits particular attention, as by it the inconveniences of the older method of a weighted belt and cone, and those of the more recent disc frames, are entirely overcome. The principle of this improvement consists of driving a pulley by pressure between two discs running at equal speeds in opposite directions, as seen at *figs.* 834, 835, 836.

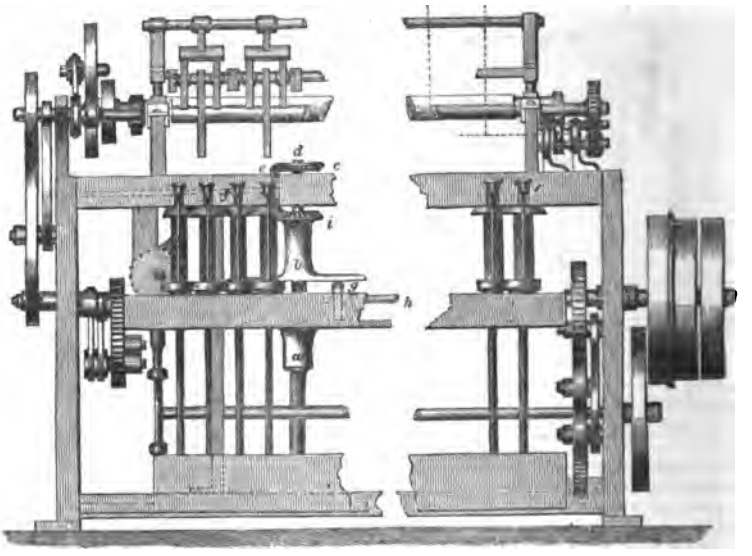
Figs. 834, 835. To obtain the variable speed, instead of using a cone and belt as in some frames, or the pulley and single disc as in others, *a b*, the horizontal driving discs, the lower one *a* is keyed to the shaft *d*, while the upper *b* is free to turn upon it; *i*, bevel wheel fitted to or forming one piece with the upper disc *b*; *c* bevel wheel keyed to shaft *d*; *e* intermediate bevel wheel gearing in the bevel wheels *c* and *i*, so as to turn them in opposite directions, and consequently the discs to which they are directly or indirectly attached; *g*, the variable pulley covered with leather and resting upon the lower disc *a*, and itself pressed upon by the weight of disc *b*; it is thus driven at speeds varying according to its approach to or from the shaft *d*, thus answering the purpose of the traversing leather belt of the cone movement; *h*, shaft keyed in the pulley *g*, from which the variable motion is transferred to the bobbins.

834



A series of preparing machines, termed a "system," consists in general of 1 spreading of 4 slivers at the drawing rollers, united into one by the doubling bars at the delivering roller, 2 frames of second drawing, in all 24 bosses 2 frames, third drawing containing

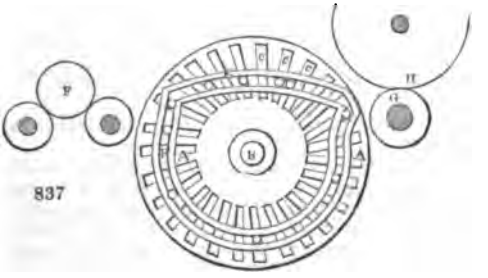
835 836



together 36 bosses; if a fourth drawing is required, 2 frames of 24 bosses each, or 48 bosses in all. 180 spindles of roving in 3 frames will well supply 3000 spindles of medium spinning. The mode of using this "system" is, as has already been said, first to spread the stricks of line upon the feeding-sheet of the "spreader," then to receive the sliver or slivers there produced into cans capable of holding 1,000 to 1,200 yards of slivers. Those cans specially intended to receive the slivers from this machine, are all made to one regular weight; thus, when filled, the weight of line each contains is correctly ascertained, and by the bell motion the length is also known. Upon this basis is founded the method of producing any desired number of yarn, and by doubling the slivers, a degree of equalisation that the simple spreading would be unable to effect; for at each drawing, and at the roving, several of the slivers from the preceding drawing are put together, to be again reduced to one for this object alone. Hence, the weight of a determinate length in yards of the desired yarn being known, a calculation is made, combined of the drafts and number of doublings the material has to undergo, to determine what the weight should be of that length of slivers contained in the cans from the spreader. It is ordinary to put 10 or 15 of these "cans" together, to form what is called a "set," the slivers of which are united at the second drawing with the subsequent drawings and rovings. The combination of two or three slivers at each boss is sufficient.

Though the above is descriptive of the "gill" frames now in use, yet it should be understood they are by no means the first or only results of the attempts made to correct the defective principle of the original roller machines, which were incapable of holding or retaining the flax with a sufficient degree of regularity, owing to its unequal lengths and unadhesive nature. The consequences were that the yarns produced were "lumpy" and unlevel, making it evident that some improved means were necessary for more completely restraining and regulating the drawing of the fibres. The most obvious way to do this was to introduce some mode of partial detention by creating a friction among the fibres to imitate the action of the fingers in hand-spinning. This led to causing the slivers to pass through and among several ranks of serrated pins, which was found very nearly to attain the object, and certainly greatly improved the levelness and uniformity of the slivers. Thus the use of "gills" became general about thirty years since.

Those first brought into general use were constructed with circular discs or plates for carrying the faller or gill bar, which at the same time were guided by their ends passing in fixed slides, so as to bring the gill in as vertical a position and as near the drawing roller as possible. The figures (837, 838) are profile and front views of the working parts of one of these gills: — A, slotted plate or disc, of which a pair were keyed upon a shaft B, so as to carry each end of the faller D, passing through the slots *c c*; E, the fixed eccentric slide; G, H, the drawing rollers; F, the holding rollers.



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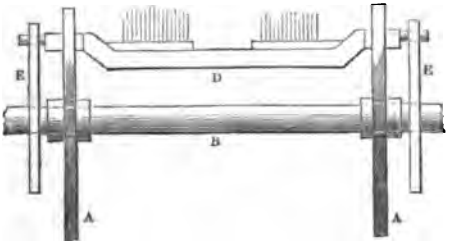
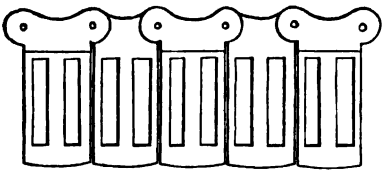


This was succeeded by the "chain gill," in which the fallers were carried forward by an endless series of connected links, or jointed together "slotted plates," instead of the simple circular. The object of this was to increase the flat surface of gill bars between the holding and drawing rollers, making it more suitable for the longer descriptions of material. The slides and rollers, being similar in these machines to those in the former, are not repeated, but the sketch of five slotted plates is given in *fig.* 839.

From the evident impor'ance of bringing the retaining effects of the gills as closely

as possible to the point where the movement of the drawing fibres is greatest, several attempts have been made to improve the above described gills in this respect. With this view Messrs. Taylors and Wordsworth patented a gill of considerable ingenuity (*fig.* 840), which therefore deserves mention, though it never came into use. Its description is as follows: —

839



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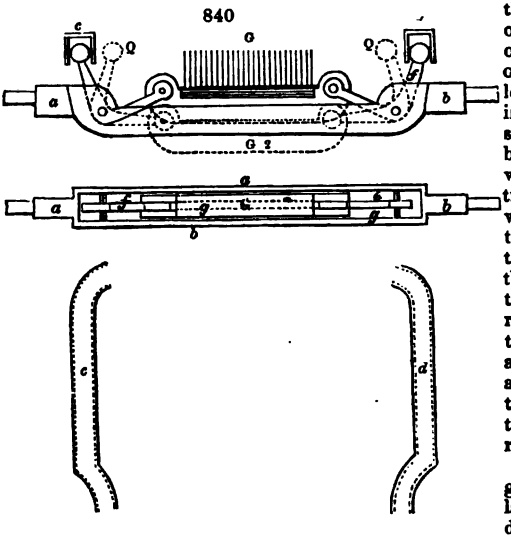

a, *b* the faller or "gill bar" in one piece, which was carried forward by an endless chain; *c*, *d*, slides placed horizontally over the gill sheet guiding the ends of certain bell-cranks *e*, *f*, joined at their angle in the recess *f*, *g*, *e*, of the gill bar, and at their other end to the gill or comb G. By this arrangement, as long as the bell cranks are in the parallel parts of the slides *c*, *d*, the gill teeth will be above the faller *a*, *b*, but when they arrive at the contracted part the guided ends will be brought into the position Q Q, and consequently the gill depressed is G 2; this is so timed as to cause them to clear the drawing roller, when, on again continuing their course, they are again caused to rise and penetrate the sliver by the reversed inclination of the slides *c*, *d*, at the back roller.

The objection to this ingenious machine was the largeness of the space suddenly left open by the descent of the gill, as the double faller, bell crank, and gill necessarily occupied great width.

The screw or spiral movement of the fallers, which was soon afterwards invented, quickly superseded all others in use, as by these means the faller was caused, even in the manner they were first constructed, to approach closer than even in the most perfected construction of the others, to the side of the drawing roller, and still maintain the pins in a vertical position. Recently this object has been more perfectly attained by a patented improved construction adopted by Messrs. P. Fairbairn and Co., whereby the obstacle to the faller wholly touching the roller has been removed, and thus producing the full holding effect of the gill to the latest possible moment. This is effected by employing a method of supporting the spirals by their working in tubular recesses in the side plate of the machine; along these recesses are longitudinal openings through which the faller end passes to enter between the threads of the spiral, and which serve also as slides to support the faller. As by this means the supports or plummer blocks that intervened between the end of the spirals and the roller are suppressed, the faller is enabled to advance to the place they formerly occupied. *Figs.* 841 and 842 show this comparison of the older and more recent methods. A, B, spirals; C C, the parts by which they are supported, being in *fig.* 841 small pivots in plummet block D D, and in *fig.* 842 hollow tube-like recesses in frame plate C C; E E, pinions to work the upper and lower spiral together; F, bearings; G, drawing-rollers; H, pressing rollers; I I, passage of the faller's descent.

Here it may be as well to observe that the same parties have still more lately introduced another important amelioration in these machines for remedying the noise and wear and tear which ordinarily attend them by the abrupt and violent descent of the faller. *Fig.* 843 shows a sectional front view of a head having this improvement applied. A A, supports for screws; *b*, *c*, top and bottom screws; *d d*, the new cams

fixed on shafts parallel with the screws, and revolving at the same speed. Thus, these cams *d d* receive the faller *e e* at their largest diameter, at the moment they are free to descend, and guide them gradually down to the lower slide.

Thus constructed, the "screw gill" continues to be the most esteemed in principle, though not without some serious objections in practice. For the abrupt and angular movement of the "faller" even here not only liberates too suddenly a portion of the

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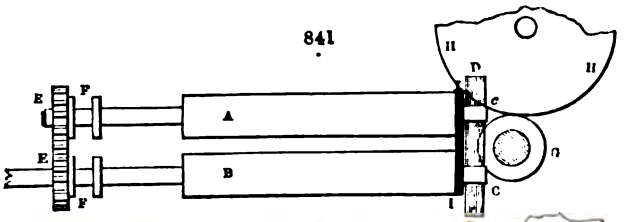

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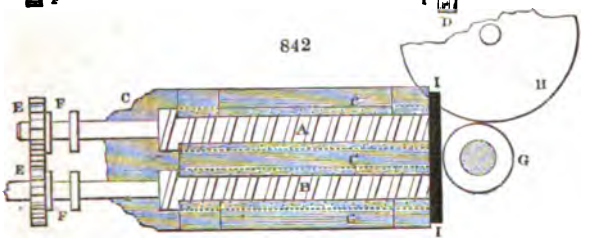
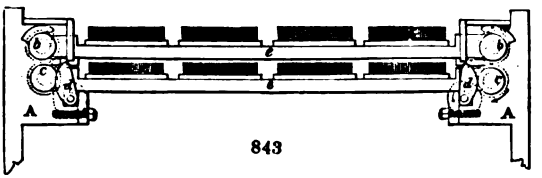


fibres that should be but gradually relaxed at the moment of being drawn, but causes considerable wear and tear to itself, the slides, and the gills attached to it; to which cause of destruction must be added the great friction of the worm movement; these, however, in "line" preparing, where the fibres are long and straight, and the drafts employed large, and where, consequently, a comparatively slow movement of the



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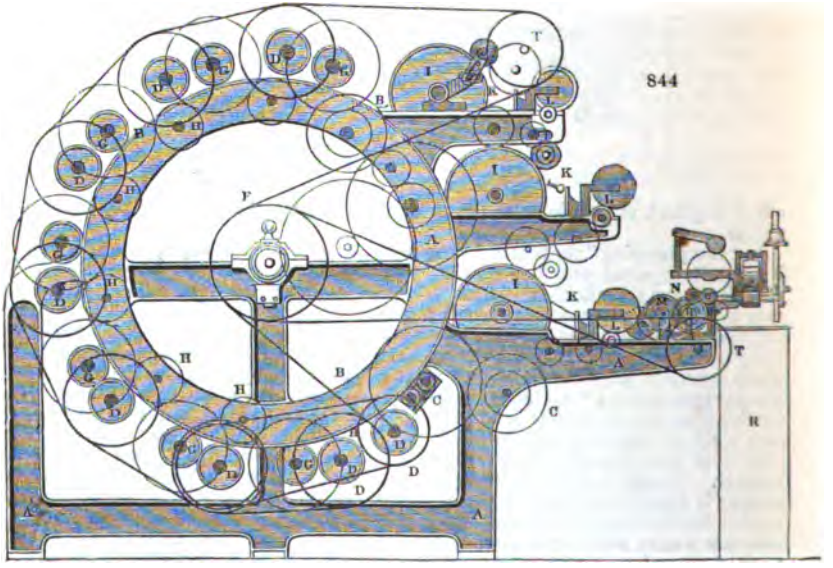
gills is required, are not so much felt as in the preparation of tow, where they become serious.

In "tow preparing" the first operation, as before stated, consists of "carding," which is generally repeated over two separate machines, which are respectively called the "breaker" and the "finisher" cards. They are essentially the same in principle, and vary but little in construction, the only difference being that the "breaker" is fed or supplied by the disjointed parcels of tow from a creeping sheet (as the spreader with "line"), and delivers its slivers into a can, whereas the finisher is fed from a bobbin upon which several of the slivers from the "breaker" are united by a machine expressly for that purpose, called a "lap frame;" this card thus receives its supply of work in a very regular form, and previously to delivering it in the form of slivers causes them to pass over a gill, to consolidate and strengthen them before delivering them into the receiving can; it is also generally clothed with a finer description of wire filleting than the breaker. Though it is the better method to card thus the tow twice, yet this second carding is sometimes dispensed with; in that case this auxiliary "gill" is similarly fixed to the first card or breaker. The cards employed for tow are machines of considerable weight and importance, the main cylinder, or, as it is sometimes called, "swift," being from 4 to 5 feet diameter and 4 to 8 feet long; those most generally employed are 6 feet long. Previously to entering upon the detailed description of a card, it may be as well first to trace in general terms the progress of its operations, as tending to elucidate the explanation of the machine itself.

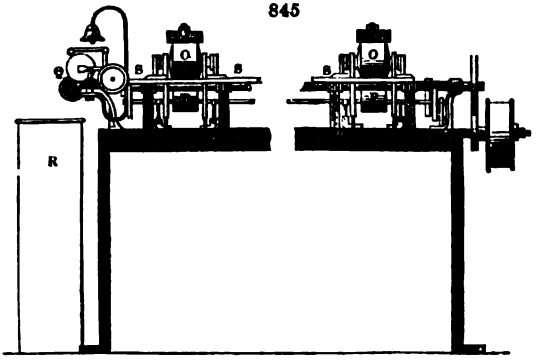
The tow is first divided by weighing into small parcels of 10 to 20 drams; these are then shaken out and spread so as to cover certain definite portions of the creeping feeding sheet, by which they are conducted to the first pair of rollers, called the feeders. These rollers are covered with a leathern band, in which are fixed in close array a number of wire points about ½ an inch long, and having a tangential inclination to the circumference of the rollers, which are about 2½ inches diameter. The tow passing at a slow rate of progression between these rollers, is by them gradually presented to the points with which the swift is likewise covered, also set in leather bands, but which are about 2 inches wide; these points, the same length as those of the feeders, have an inclined direction pointing to that in which the cylinder turns. The much greater velocity of the "cylinder" combs and somewhat opens and breaks the tow as it slowly arrives in contact, and the inclination of the pins at the same time carries it forward. All such lumps and fibres as are not sufficiently opened and straightened by this first contact, remaining prominent on the surface of points on the cylinder, are carried by it against another roller, whose axis is parallel, and whose wire-covered circumference is brought as near as possible, without absolute contact, in order to catch and retain these prominent lumps and fibres; the points of this roller (called a "worker") are inclined in a direction opposed to the movement of the swift, and, therefore, hold the "tow" to be again combed and straightened as at first it was by the feeders: this is repeated eight or nine times, by having that number of workers to the card; each of these workers has its attendant roller, also covered with wire points, by whose inclination in a contrary direction, and by the greater velocity of the roller, the tow is stripped from the workers, to be again laid on to the cylinder. The strippers, though running at a greater velocity than the workers, are still slower than the cylinder. The tow thus carried forward gradually improving in openness and regularity as it passes each pair of "workers and strippers," finally arrives at the roller called a doffer, of which there are two or three upon a card, the wire points of which are in such a direction as to hook or catch the tow "as it flies." The use of these several doffers is, that by placing each succeeding one progressively nearer the swift, the longer and shorter fibres are successively and separately taken off. Each doffer is cleared by an oscillating comb, and the slivers conducted, if intended for the lap machine, into a can by delivering rollers; but if finished, these delivering rollers are as it were the back rollers of the auxiliary gill, patented for this application by Messrs. Fairbairn and Co.; whereby the slivers are not only saved from all danger of derangement in their loose and porous state as direct from a card, but the hitherto double expense of carding and first drawing is reduced to that of carding alone.



A A A (*fig.* 844), framing; B, swift or main cylinder; C, feed rollers; D D D, strippers to feed rollers and workers driven by one belt from pulley E, and maintained

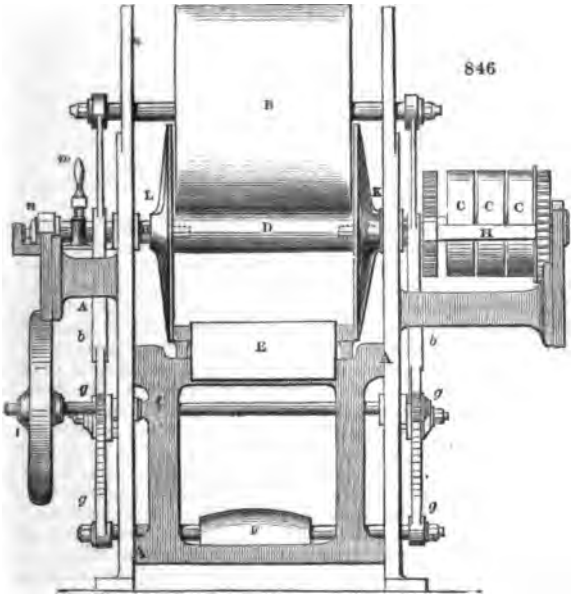
tight by the movable pulley F; G G G, workers; I I I, the three doffers; H H H, intermediate wheels to connect the movement of the doffers with one another; K K K, oscillating combs for their respective doffers; L, delivering rollers; M, back roller of auxiliary gill; N, gill surface; *o*, *p*, drawing rollers; Q, delivering rollers and bell motion for measuring the sliver in the cans R; S S, doubling plate; T, pulley for driving auxiliary gills by bell from the pulley E.

845



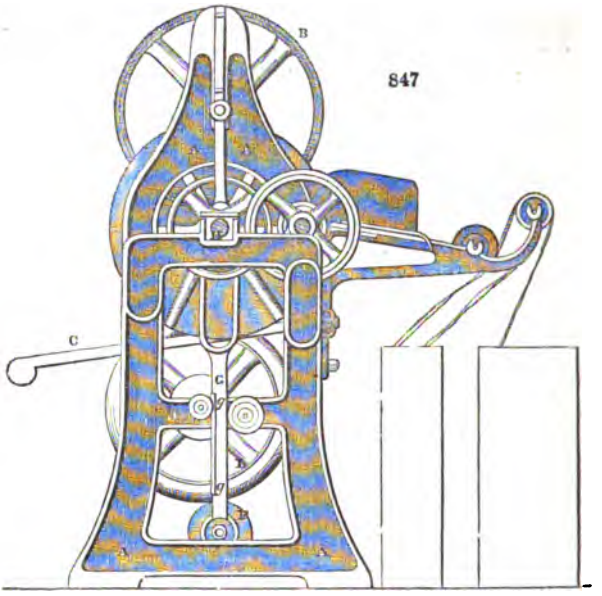
The lap frame, to which allusion has already been made as the necessary adjunct to the cards when double carding is to be performed, is employed to collect together a number of slivers from the "breaker" by winding or lapping them upon a cylindrical piece of wood, which may be described as a bobbin shank, thus producing an equalisation of the slivers of tow as the making up of sets effected in line preparing; from 50 to 60 lbs. of tow is the usual complement of one of these bobbins, the length and the diameter, when full, about 22 inches; thus, a 6 feet wide finisher card will take off these bobbins at once; from 15 to 20 is the number of slivers usually wound together, and the completion of a bobbin by the ringing of a bell, connected with the measuring cylinder of the machine. The following is a descriptive drawing of the lap machine.

846



A A A (*figs.* 846, 847), framing; B, measuring and pressing cylinder; C C C, driving pulleys connected with different gearing to change the speed as the bobbins

fill; D, bobbin or shank intended to be filled; E, table to receive the bobbin when about to be taken from the machine; F, weight to increase the effect of pressure of the



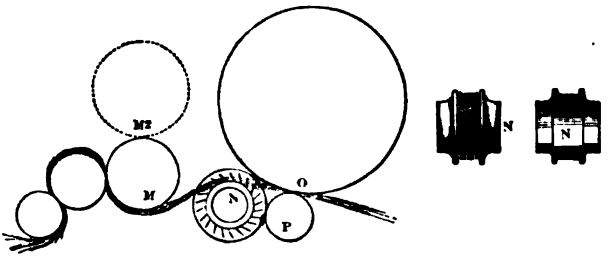
measuring cylinder by the connecting rods G G G, which are split for part of their length in order to pass the shaft H, and at another, *g g*, have racks into which work pinions keyed on the shaft of the hand wheel I, for the convenience of raising and lowering the cylinder and weight. The shaft H is divided at the plates K and L, and provided with sockets to receive the end of the bobbin shank D, which is introduced by sliding back the piece H *n*, and returning it by lever *m*, and thus is coupled and turns together with two pieces of shaft H, as also the disc plates K and L, which are to serve as temporary ends to the bobbin during the time of its filling, and thus by turning with it avoid that rubbing and felting effect upon the edges of the tow so injurious in the machines formerly constructed, and by the bobbin acting as the driver to the cylinder the slivers are drawn tighter, and thereby avoid those plaits that the other machines were so liable to produce.

As before mentioned, some objections were found to the working of the screw-gill, of a nature detrimental to the machines themselves, which, though not of great importance in "line," were much aggravated in tow preparing, as the lesser drafts there employed cause a greater wear and tear of the fallers and gills. The objection to these machines, however, is not confined to this point only, but extends also to their effect upon the material itself. The fibres of the tow sliver, as coming from the card, are in a light and much confused state, which renders them liable to be easily separated; so that the faller, by its sudden descent, has a tendency to draw some down, and become lapped by them, as well as to make so marked a difference in the thickness of the sliver, by the withdrawal of the retaining comb, so as materially to injure the quality of the yarn. Thus this "gill" was not enabled to hold its place in tow spinning, when other circumstances led to greater attention being paid to this important branch of the flax business, and it became a desideratum to have a machine free from these defects, and capable of working without derangement, at much greater velocity than was safe with the "screw-gill." These desiderata the "rotary" gill, patented by Messrs. Fairbairn and Co., amply supplies. For in this gill the circular form of the gill sheet obviates the necessity of having several fallers, and the simple motion creates neither friction nor abruptness of effect, while the retention of the fibres being continuous, the slivers produced are perfectly level and uniform; consequently these gills are extensively applied, as the auxiliary gill explained in carding, as well as for the subsequent drawings and rovings of tow, and sometimes, as will be after-

wards seen, to coarse spinning. The theoretical construction of these rotary gills will be seen by the annexed sketch.

M (*fig.* 848), back rollers, but when applied to a card a top and bottom holding rollers are again employed; N, the rotary gill sheet having the pins inclined backwards, so as to ensure the impalement of the sliver when the fibres begin to draw; P

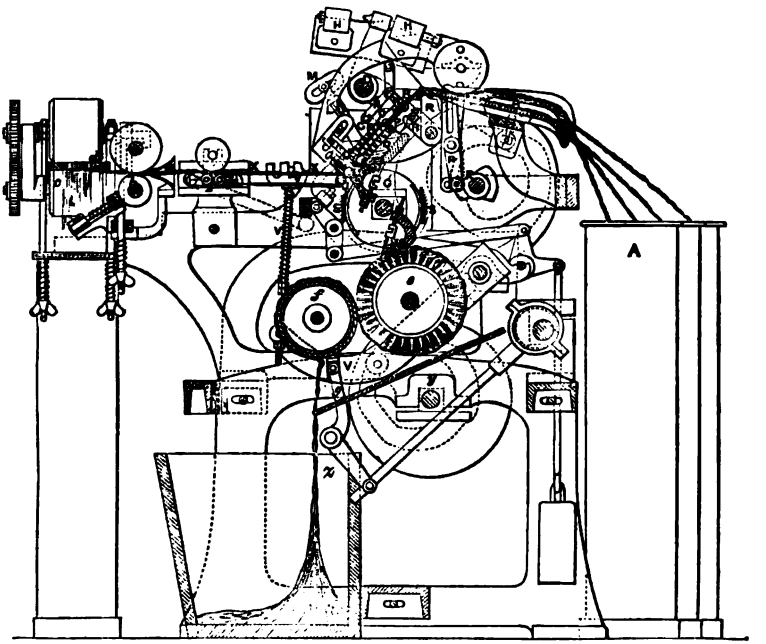
848



and O, the drawing and pressing rollers; the doubling bars or plates are the same to these gills as to the "screw-gills."

A machine has been lately invented, and brought out by Sir P. Fairbairn and Co. of Leeds, called Heilmann's tow combing machine (*fig.* 849), which, on trial, is much approved of. The tow is first carded in the ordinary way, say on a breaker card, and then on a finisher card; the latter delivers the tow in the shape of a sliver into cans, which are next placed at A, or back of the tow combing machine.

849



From the cans A the tow goes to the back conductor B, divided into as many compartments as there are slivers; and from the conductor B, to the feeding box C suspended on shaft D, without being keyed to it. The front lip E of the feeding box is

fluted and fitted with leather, and a corresponding nipper F hung from the same shaft D, and keyed upon it, completes the jaw which has to hold fast the tow, while the cylinder G combs it.

The feeding box C derives its motion from the nipper F, which is moved by lever and excentric as shown, and follows that nipper by its own weight, until stopped by indiarubber buffers H; when the nipper F in going further back leaves it, and the jaw E F opens for more tow to be fed, and the tow already combed to be drawn through the detaining comb I, as explained hereafter.

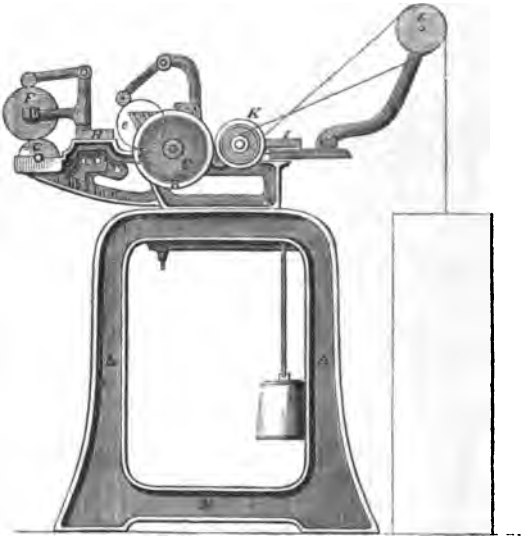
The top K of feeding box is movable up and down, by means of the connecting rod L, hung on a fixed centre M, so that the top part K opens or shuts as the body of the box goes backwards or forwards. The levers N N N are only used to keep the top and bottom of the box parallel to each other.

As shown in the drawing, the top of the feeding box is fitted with hackles passing through two grates O and P, fast on bottom of feeding box, and leaving between them a space through which the sliver has to pass.

By the above arrangement, the hackles are caused to withdraw from the tow, while the whole box is drawn backwards on slides of table Q, by the eccentric motion R R R. The last backwards motion takes place while the jaw F is yet shut, and the top of the box up; but when the latter has got closed again, then the whole box slides down on the table Q to its former position, bringing with it the sliver of a quantity equal to that move: this completes the feeding motion.

Now as the feeding box recedes, the lip E comes nearer to the combing cylinder G, the hackles S S cleaning the tow projecting outside the nipper F. As soon as they are passed through, the feeding box comes back to the most forward position, when the nipper F leaves it, and the jaw E F opens: at the same time the two rollers T U have reached their top position. The top one T is then thrown forwards (by the lever arrangement shown in V V V) upon the leather W, stretched on parts of surface of cylinder G; this roller T is thus driven, and takes hold of the points of the tow presented to it by lips or bottom jaw E; a fine detaining comb I being just before interposed between them to keep back the noils, that have not been carried off by the combing cylinder.

850



In that way the points of the tow are driven upon the sheet X, until the roller T, by being thrown back again off the leather W, their motion is stopped at the same moment, the two rollers U and T are allowed to drop down by eccentric V, drawing with them (through the detaining comb I, and quite out of the rest of the sliver) the other ends of the fibres of which they have got hold.

While this has been going on, the feeding box has advanced the sliver a step, the

nipper closed, and forced the said feeding box forwards so as to bring the lip E within the reach of hackles S on cylinder G, which then met it, cleansed the tow, and so on as before.

At that time the rollers T and U come up again, and during that upwards motion

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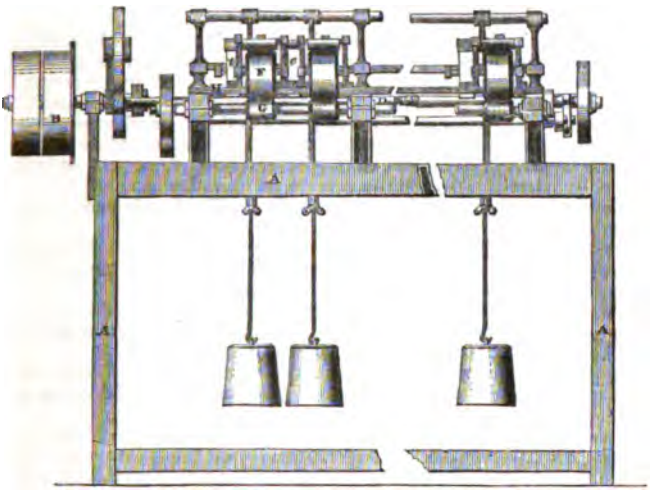

the latter ends of the fibres partly combed and overturned by the cylinder hackles, as shown in drawing, are combed by them in their turn. Then the roller T is once more driven round by the leather W stretched on cylinder, the new points place themselves

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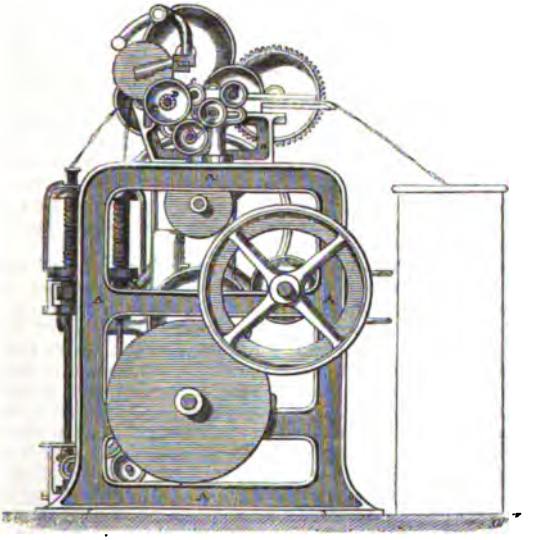

above the back ends of the fibres combed before, and are carried forwards into a continuous sliver on the leather sheet X, from the leather sheet to the rollers Z Z, then to the trumpet conductor A, the front delivery roller C, and (when more than one head to the machine) from C to the end delivery *c*, over the conducting plate *d*.

In *e*, *f*, *g*, and *h*, are the usual brush, doffer, comb, and tow box for the noils.

These combing machines are made of different sizes to suit all sorts and lengths of tow; the yarn produced from them is much finer than that produced by the ordinary carding system alone. The combed tow can generally be spun to as high numbers as the line from which it has been combed, and in some instances has produced good yarn, even to higher numbers. The combed tow, after the combing machine, is passed through a system of drawing, roving, and spinning, similar to that used for cut line.

Subsequently to the carding the preparation of tow is completed by making up sets of cans for the second drawing, as explained for line; these slivers are doubled and drawn once or twice more, and then roved. The drafts used in tow preparing are from 9 to 8, for, as the fibres are shorter, it necessitates the employment of less draft. In both line and tow preparing, lesser drafts are employed as the stages advance, the gills finer, and the conductors narrower: also for both materials much attention is requisite to keep the various parts of the machines in good order, free from bent or broken pins, and chipped or indented rollers, for no subsequent operation can cure the defects that may be produced by negligence in these particulars. The drawing and roving frames for tow are shown in *figs.* 850, 851, 852.

A A (*fig.* 851), drawing frame; B, driving pulleys; C, rotary gill sheet; D, drawing roller; E, pressing; F, G, pairs of delivering rollers; H, doubling plate; I, back conductor; K, back roller wheel with pulley to turn the sliver rail L.

A A (*figs.* 851 & 852), roving frame; B, pulley and fly wheel combined; C, drawing roller; D, rotary gill; *a a*, stand for gill movement. The regulation of the bobbins is effected in the same manner as already described for line roving.

Spinning. — This operation consists in drawing the "rovings" down to the last degree of tenuity desired, and twisting them into hard cylindrical cords, which are called "yarns."

There are three modes of performing this operation; the first, and perhaps oldest, is that where the drawing and twisting are performed altogether, with the material preserved dry, and without breaking or shortening the fibre; the second is that which likewise, without changing the length of the fibres, draws them while dry, but wets them just at the moment before twisting. This method is the nearest imitation of hand spinning, and makes the yarn more solid and wiry than the first; as the fibres of flax losing their elasticity while wet, unite and incorporate better with one another. The third mode of spinning has been much more recently introduced than either of the others, and by it the fibres are wetted to saturation previously to being drawn, whereby they are not only much reduced in length, but their degree of fineness is increased by the partial solution of the gummy matter, inherent in the flaxen material: owing to these circumstances equally good yarns can be produced by this mode of spinning from line and tow of inferior quality, to what could be employed upon either of the others, and not only that, but much finer yarns can be now spun than were possible previous to its introduction. It has therefore not only nearly superseded all other methods of spinning for yarns from 20's to the finest, but has much increased the extent and importance of the flax manufacture.

The only difference in spinning frames for "line or tow," when employed for the older methods, consists in the length of reach, which generally involves the necessity of having separate machines for each material, though sometimes they are made with a capacity to be adapted to either purpose. In the third method the same machines are used promiscuously for "line or tow."

The yarns spun wholly dry are used for the coarse description of woven goods, as packing canvas, corn sacks, and, when partially bleached, for sheetings and towellings, as from its greater elasticity and openness it fills up better in weaving. Those spun partially wetted are employed for a somewhat superior description of linen goods, and the solid silky appearance qualifies them for drills, damasks, &c., as well as for sewing and shoe threads; a somewhat inferior material, by this manner of treatment, makes an equally good yarn as a better material spun dry. The yarn produced from this wet principle is rather inclined to have a cottony appearance, and from the comparative ease with which an inferior material can be made to present an apparently fine good yarn, the application of yarns thus produced is exceedingly various and sometimes deceptive, though when good materials are used, these yarns afford durable and handsome drills, shirtings, lawns, and cambrics, as well as fine sewing threads.

The mechanical arrangements for twisting, and then winding the yarn upon a bobbin, is called the "throstle" principle, supposed to be so called from the whistling noise they create when working at full speed, which is from 2,500 to 4,000 revolutions a minute. The following diagram will explain the principle, which is applied alike to all the modes of spinning above described.

A A (*fig.* 853), the spindle; B, the bobbin, loose and independent of the spindle in

regard to turning, and rising, and lowering, but through which the spindle passes; CC, the flyer screwed to the spindle top; D, table called bobbin lifter, as while at work it rises and lowers to lay the yarn on the whole bobbin equally; E, a small cord to press on the bobbin by the weight F: G, pulley by which the spindle is driven.

Many attempts have been made to improve upon this principle, in order to avoid or lessen the strain upon the thread in its passage from the drawing rollers to the flyer eye; but, till recently, without any degree of success. The only improvement at present known, and which promises to become general, is that where the necessity to have a top to the bobbin is avoided. It will be seen from the above

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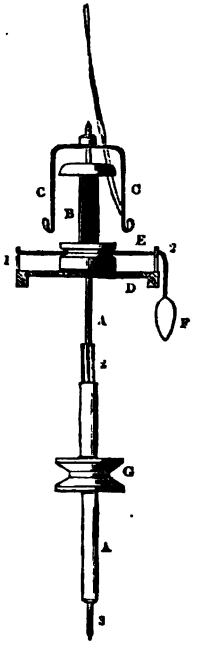

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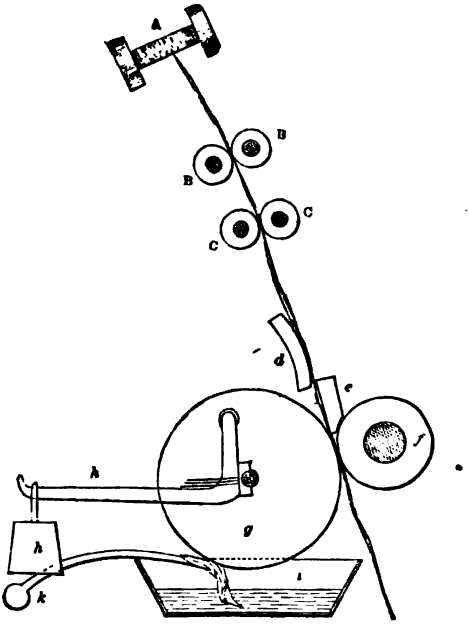

diagram (853), that the yarn is compelled to rub the top of the bobbin, and the friction thereby created quickly causes it to become rough; and therefore it has a tendency to catch and break the thread. The desirableness, therefore, of having a clear course for the yarn was evident, and this improvement that we are about to explain produces the effect by employing what is called a coping motion, which, like that used in mulespinning, preserves the layers of thread upon the bobbin ever in a pointed or conical state, and therefore self-supporting without the aid of the wooden end of the bobbin. See COTTON SPINNING.

The arrangement of the rollers for holding and drawing the slivers or rovings, as well as the plates and rollers for aiding to retain the twist of the rovings, in order to render their elongation more equable when to be drawn dry and spun upon the older methods, will be seen in *fig.* 854.

A (*fig.* 854), roving bobbin; B, back or holding roller; C, carrying roller; *d*, flat plate with a slightly curved face; the carrying roller and plate are so placed as to cause a degree of friction to the roving when passing over them, so as to retain the twist, and thus act as the pins in the "gill frames;" *e*, tin conductor for contracting the roving at the moment of being drawn; *f*, metal roller; *g*, wooden roller pressed against the drawing roller in order to pinch the roving; *h*, lever and weight. When it is intended to wet the yarn previously to twisting, the trough *i* is used, in which is water, which is supplied to the roller *g* by the capillary attraction of a piece of cloth immersed therein, and bearing against the roller by lever *h*.

The machines for "wet" spinning are of a very different construction and appearance; as the close proximity of the holding and drawing rollers prevents the inter-

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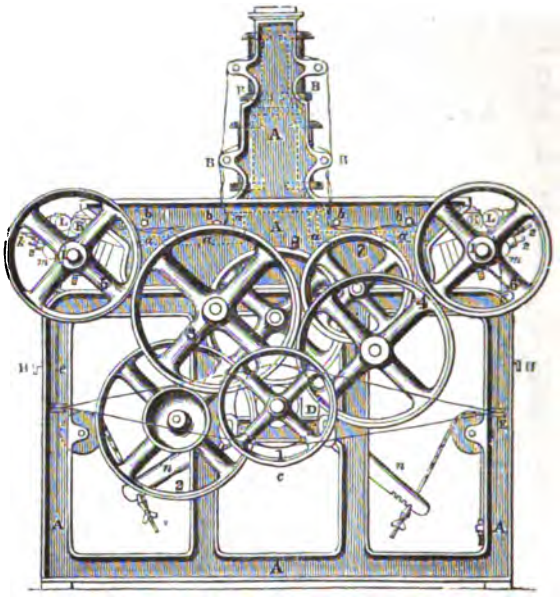

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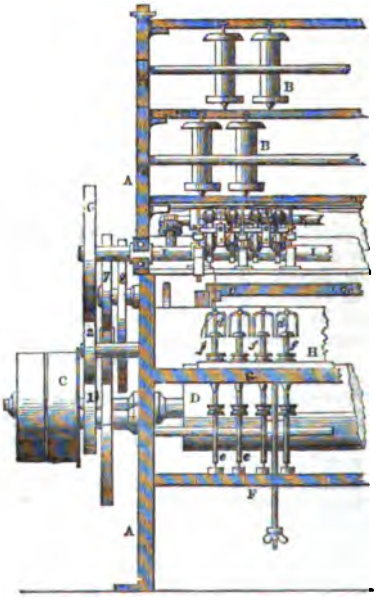

vention of holding rollers or friction bars, while the force requisite to draw the rovings at the short reaches used, varying from 2½ to 4 inches, requires each pair to be deeply

and accurately fluted into one another. The water used is heated, in order by the expulsion of the fixed air more rapidly and completely to saturate the rovings while passing through it. The following drawings and description will be sufficient to give an accurate idea of the principle of these machines, which are generally 20 to 30 feet in length, and contain 200 to nearly 300 spindles; that is, 100 to 150 on each side.

A A A A (*figs.* 855 & 856), framing; B B, stand for roving bobbins; C, driving pulleys fixed upon the axle of cylinder D, from which pass endless cords to drive the spindles *e e*; F, step-rail of spindles; G, collar rail for ditto; H, bobbin lifter; I I, front roller; K K, back roller; L, back pressing roller; M, top pressing roller (these are generally made of box wood, but sometimes of gutta percha); N, N, levers in connection with the excentric to produce the rise and fall of the bobbin lifter; O O, thread-plate; Q Q, saddles or transverse bars resting on the axles of the back and front pressing rollers, so that one lever and weight acts for both by the connecting rod and lever *r r*, which, in order to cause more pressure on the drawing than on the back roller, is placed on the saddle nearer the former than the latter. 1, 2, 3, 4, 5, 6, 7, 8, train of wheelwork, by which the movements are distributed. *a a a*, the trough of hot water maintained by steam-pipes at the desired temperature; *b b*, guide rods or pipes to cause the roving to pass under the water. In order to avoid the rollers becoming indented by the roving always passing on the same place, they are caused to traverse the breadth of the rollers by a traversing guide rail, moved by an excentric at the worm and wheel *c*; *d*, flyers, and *f*, spindles.

Here it may be proper to introduce a description of the machines for twisting the yarns when spun into "threads" used for sewing, &c. The yarns spun for this purpose should always be made of a somewhat superior description of line to that employed for the same number of yarns for weaving, and have rather less twist. They are generally taken while wet on the spinning bobbins to the twisting frame, and, when combined together, the union is effected by a torsion in the opposite direction to the original twist of the separate yarns.

Reeling.—This operation consists in winding the yarn off the bobbins of the spinning or twisting frames, and forming it into hanks or skeins. The various denominations of the skeins into which yarn is reeled, and then the forms or combinations they are made up into, are as follows: —

The lea containing	300	yards
10 leas making		1 hank
20 hanks	„	1 bundle
6 bundles	„	1 packet.

It is by the standard lea of 300 yards that the description of yarn is known from the number contained in 1 lb. weight; thus, No. 20 contains 20 leas or 6000 yards for 1 lb. weight. In Scotland, the subdivisions are rather different from the foregoing, which are employed in England and Ireland; the lea, however, remaining the same: —

38 leas make		1 spindle
6	„	1 rand
12 rands	„	1 dozen.

The reeling is performed upon exceedingly simple machines, generally put in motion by the hand of the person attending them, though sometimes they are driven by the motive power of the factory. The reel is made sufficiently long to receive twenty bobbins, and the barrel upon the yarn is wound in one length; the diameter, however, varies so as to suit the different sizes yarned to be reeled. For the coarsest yarns and down to 16 and 20, the largest circumference is used of 3 yards, from that to about No. 100, 2½ yards, and for the finest yarn 1½ yards is found most convenient. These various circumferences are compensated either by putting a great number of threads into each "tye," or increasing the number of tyes, so that opposite to each one of the 20 bobbins an entire hank should be formed before taking the yarn off; thus at each "stripping," one bundle is turned off. To facilitate the stripping, one of the rails of the barrel is made to fall in, and thus slacken the hanks; care is taken to leave the lea bands very loose, in order to allow the yarn to be spread out in drying and bleaching. The determinate lengths of yarn, when wound on the reel, are notified by the ringing of a bell connected with the axle of the barrel. *Fig.* 857 below shows the form of an ordinary hand-reel.

A A (*fig.* 857), framing: B B, reel barrels; C, box or trough to receive empty bobbins, &c.; D D, bobbins in position of being reeled; E E, guide rails, movable so as to place the leas side by side on the reel; *f f*, bell wheels; *g g*, bells for each reel barrel suspended on springs.

To these hand-reels there are many objections; for it is evident that the correctness of measure depends entirely upon the attention of the reeler, and the stoppages arising from the breaking of a thread or the finishing of a bobbin interrupt the work of all the others. These objections rendered it necessary to attempt some ameliorations of the system by the introduction of a reel that should automatically prevent these causes of error. Such a reel was patented a few years since, and is now in general use in Scotland; it is so contrived as to have the capacity of stopping itself when a thread breaks, when a bobbin finishes, and leas and hanks completed; and having but four or five bobbins in one compartment, the stoppages affect but few at a time; and as this machine can be worked by less skilful persons without possibility of error, much saving is effected both in wages and material. The annexed figure (858) shows the principle of this improved reel.

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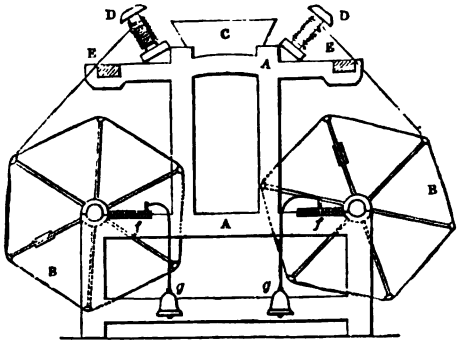

A A (*fig.* 858), framing; B reels; C C, pendulums on which are hung the bobbins to

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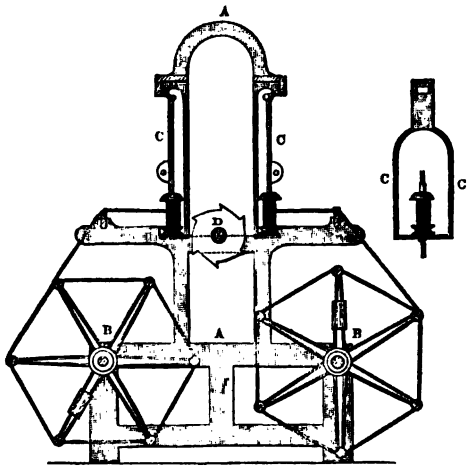

be wound off; D, driving shaft with ratchet wheels opposite to each pendulum, so that when a thread breaks, the pendulum to which it is attached falls into the ratchet wheel, and thus stops it.

The drying of wet spun yarns should always, when possible, be done in the open air by spreading the hanks upon horizontal poles through them, with another similar pole resting inside upon their lower extremities, in order to keep them straight. If artificial heat is employed, that from steam or hot water is preferable, and it should never exceed 90° Fahr., as otherwise the yarn is apt to become harsh.

Making up.—By this operation is first produced upon the yarns a certain softness and suppleness, and then the hanks are folded and tied up in conveniently-sized packages.

In order to give the yarns that soft and mellow feel so agreeable and characteristic of flax yarns, the hanks when brought from the drying are what is called shaken

down and pin-worked. This is done by separating a few at a time, and passing them on to a strong arm of wood fixed to a wall or pillar, when with a heavy baton put through them, the workman proceeds to stretch the hanks with a sudden check or jerk, which operation he repeats in two or three places so as to thoroughly straighten and shake them loose; he then, using the same baton as a lever, twists them lightly backwards and forwards till the desired degree of suppleness is obtained. A brush is sometimes used to aid the straightening and separating, as well as to increase the gloss on the yarn. The hank or hanks will then be found to have assumed a flat shape, as on the reel, which facilitates their folding with a dexterous twist by their middle, when they are laid in square piles upon a table with their twisted folds one upon another. They are maintained in the perpendicular by a few supports fixed in the table. Sometimes these packages, which, according to the sizes of the yarn, consist of from ½ of a bundle to 5 or 6 bundles, are bound together by some of their own hanks, but sometimes by cords in three or four places of their length. It is, however, better to employ a bundling press than an ordinary table, as the yarn can then be made up more solidly, thus both improving its appearance, and causing it to occupy less space for packing and stowage. The bundling presses are made upon the same principle, but on a smaller scale, for making up the small packets in which sewing threads are generally presented for sale, and are upon the following construction (*figs.* 859, 860).

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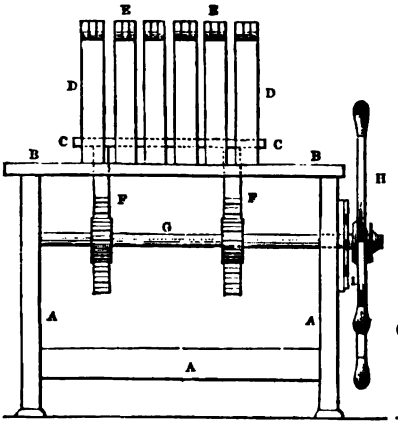

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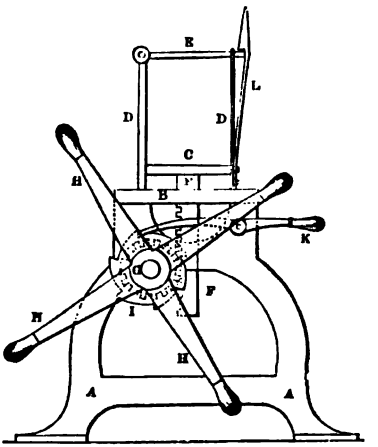


Fig. 859, front view; *Fig.* 860, profile. A A A, frame; B, table or flat top of frame; C, rising table; D D, iron uprights fixed to B; E E, bars hinged at one end to uprights D D, to shut across the press, and be caught and latched down by the spring catch L, fixed to the upright D along one side of the press; F F, racks for lifting the table C by the pinions on shaft G; H, crossed levers for turning the shaft G; I, ratchet wheel engaging the detent K, and thus retaining the shaft G in any required position, and thus of course maintaining the pressure of table C against the top cross-bars E.

Weaving, is the operation by which the yarns are combined into textile fabrics, such as canvass, linens, lawns, drills, damasks, &c., and a great variety of other denominations of article for use and ornament.

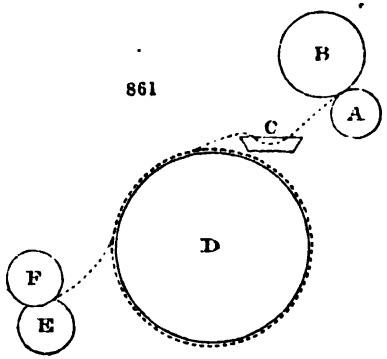
Hitherto the weaving of linens has been carried on by the ancient and well known hand process, so ancient and so well known as to place the operative practising it among the worst paid of any other art. Now, however, there are several extensive and thriving establishments where machinery has taken the place of much squalid misery, and at much cheaper rates produce to consumers superior articles, and still afford good payment to the operative. The improvements in power weaving which have led to this result are not founded upon one or even a few successful inventions or contrivances, but are the combination of a great many that have occupied much time to mature. Many difficulties had to be overcome in the weaving of flax that did not exist in that of other materials; and for a considerable period the expense of linens rendered their consumption so limited, as to make their production by power weaving

but a very secondary object, The greatest obstacle of a practical nature to the introduction of the power loom weaving of linens was, the stubbornness or want of elasticity in the yarn, which caused frequent breakages, and much confusion. In woollen or cotton goods, if a thread or yarn should chance to be a little tighter than the others in the warp, its elasticity will allow it to come up to the general bearing of the others when the weft is struck up by the reed; but in linen from the want of that elasticity, a thread so situated would break, and by crossing some others, cause those also, if not to be broken direct by that circumstance, at all events to produce an obstruction to the shuttle that would lead to further mischief. Hence it was most material in linens to have such a method of winding the yarns upon the warp beams that should insure the greatest regularity; but strange to say, that point, though now attained, was at first wholly lost sight of. That circumstance, as well as the great mistake of attempting to use the same looms as are found suitable for cotton, produced so much discouragement in the earlier attempts as to give rise to a high degree of prejudice against the possibility of success in this undertaking, which may account for the backwardness in which this branch of the flax manufacture was found till quite recently.

The roving machine, called by the ingenious inventor, Mr. W. K. Westley, of Leeds, the SLIVER ROVING FRAME, seems to be a *philosophical induction* happily drawn from the nature of the material itself, and accommodated to its peculiar constitution. It is remarkable for the simplicity of its construction, and, at the same time, for its comprehensiveness: requiring no nicety of adjustment in its application, and no tedious apprenticeship to be able to work it.

It is known that the mucilaginous matter of the plant may be softened by water, and hardened again by heat; of this fact advantage is taken, in order to produce a roving wholly without twist; that is, in the form of a ribbon or sliver, in which the fibres are held together by the glutinous matter which may be natural to them; or which may, for that purpose, be artificially applied. The sliver roving, as long as it remains dry, possesses all requisite tenacity, and freely unwinds from the bobbin, but on becoming again wetted in the spinning frame, it readily admits, with a slight force, of being drawn into yarn, preserving the fibres quite parallel.

The diagram, *fig.* 861, shows in explanation, that



861

A, is the drawing roller of the roving frame in front of the usual comb.
B, the pressing drawing roller.
C, a shallow trough of water.
D, a cylinder heated by steam.
E, a plain iron roller for winding.
F, a bobbin lying loose upon the winding roller, and revolving upon it, by the friction of its own weight.

The roving, or sliver, as shown by the dotted line, after leaving the drawing rollers, A, B, passes through the water, in the trough C, which softens the gluten of the fibres: and then it is carried round by the steam cylinder D, which dries it, and delivers it hard and tenacious to the bobbin F, on which it is wound by the action of the roller B.

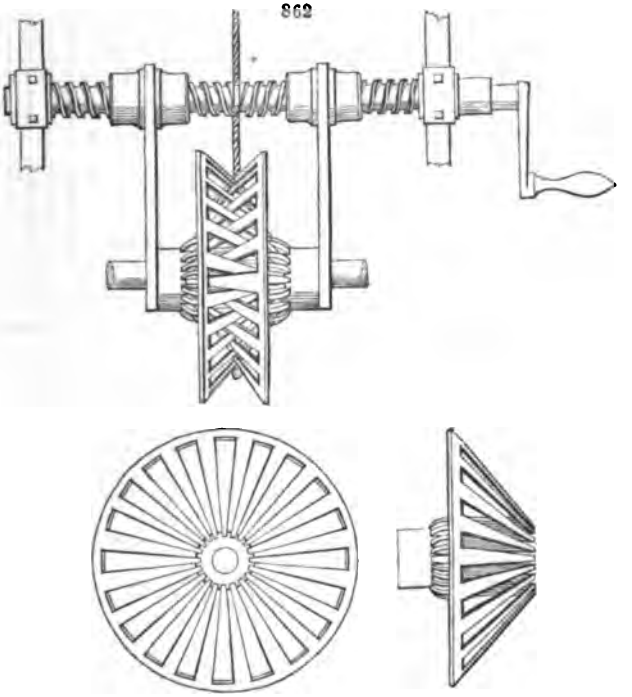
This is the whole of the mechanism required in producing the sliver roving. All the complex arrangements of the common cone roving are superseded, and the machine at once becomes incomparably more durable, and easier to manage; requiring only half the motive power, and occupying only half the room. A frame of 48 bobbins is only 6 feet long, and affords rovings sufficient to supply 1200 spinning spindles.

This machine, though here described, is but little used, being capable of but very limited application.

Combe of Belfast has lately introduced an improvement in the roving frame. It consists in the application of a peculiar expanding pulley, instead of the cones, or discs and runners which have hitherto been always used for the purpose of regulating the "take-up" of the bobbins. It is evident that a strop of 2 or 3 in. broad, working over the cones, placed with the small end of one opposite the large end of the other is an imperfect and rude mechanical contrivance, and that there must be a constant straining and stretching of the belts. There is the same imperfection attending the disc and runners. The expanding pulley is free from these objections, as its acting surface is a line; and therefore it works with the greatest accuracy, while it is also a great simplification of the machine generally. In rovings for flax and tow it is

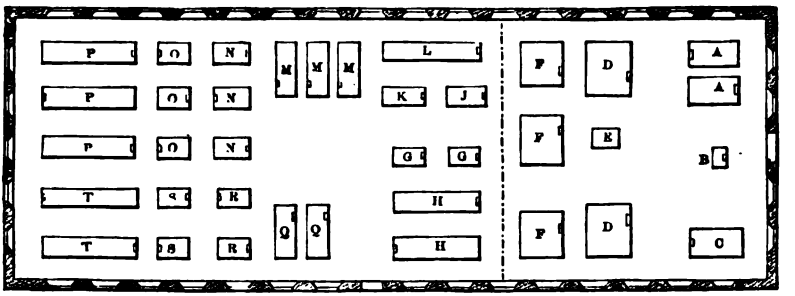
generally driven directly from the front roller, by which means a large number of wheels and shafts are avoided.

862



The following sketch shows the arrangement of the machinery in the most important rooms in a modern flax mill of 7000 to 8000 spindles, capable of producing, weekly, about 1900 bundles of line yarn, No. 25's to 120's; and about 700 bundles of tow yarn, No. 10's to 40's.

863



There are three systems of long line machinery for No. 25's to 70's; two systems of cut line machinery for No. 10's to 120's; and three systems of tow machinery for No. 10's to 40's.

The building is 56 feet wide and 162 feet long; which is a very suitable and convenient size, and which admits of the most economical arrangement of the machinery. The following is a description of the machines shown in the preparing room: —

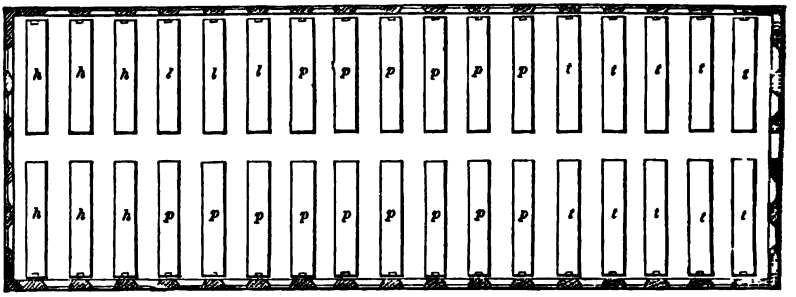
A A, two of Baxter's patent sheet hackling machines for long tow.

B, a flax-cutting machine.

C, one of P. Fairbairn & Co.'s patent double line of holder hackling machines for cut line.

D D, are two breaker cards, 4 feet diameter × 6 feet wide.
E, lap machine.

864



F F F, are three finisher cards 4 feet diameter × 6 feet wide, with P. Fairbairn and Co.'s patent rotary gill drawing heads attached.
G G, are two patent rotary gill drawing frames for long tow, 12 slivers each.
H H, two ditto regulating roving frames, 48 spindles each, for long tow.
J, is a screw gill second drawing frame of 3 heads for cut line tow.
K, is a screw gill third drawing frame of 3 heads for cut line tow.
L, a screw gill regulating roving frame of 72 spindles for cut line tow.
M M M, are three long line first drawing frames or spreaders of 4 bosses each.
N N N, are three long line second drawing frames of 2 heads each.
O O O, are three long line third drawing frames of 2 heads each.
P P P, three long line regulating roving frames, 60 spindles each.
Q Q, are two cut line spreaders of 4 bosses each.
R R, two cut line second drawing frames, 2 heads each.
S S, two cut line third drawing frames, 2 heads each.
T T, two cut line regulating roving frames, 72 spindles each.

The spinning room contains 34 spinning frames of 184 to 244 spindles each, apportioned to the several systems as described below.

I. System of long line machinery for spinning No. 25's to 40's.
1 Baxter's patent sheet hackling machine, 6 tools.
1 spreader or first drawing frame, 4 bosses.
1 second drawing frame, 2 heads, 4 bosses each.
1 third drawing frame, 2 heads, 6 bosses each.
1 patent disc regulating roving frame, 60 spindles, 10 spindles per head, 8 inches × 4 inches bobbin.
5 spinning frames, $2\frac{3}{4}$ inches pitch, 200 spindles each, 1000 spindles.
The production of this system is about 66 bundles, or say, 420 lbs. of No. 30's yarn per day.

II. Two systems of long line machinery for No. 40's to 60's.
1 Baxter's patent sheet hackling machine, 8 tools.
2 spreaders or first drawing frames, 4 bosses each.
2 second drawing frames, 2 heads of 6 bosses each.
2 third drawing frames, 2 heads of 8 bosses each.
2 patent disc regulating roving frames, 60 spindles each, 12 spindles per head, 6 inches × $3\frac{1}{2}$ inches bobbin.
10 spinning frames, 220 spindles each, $2\frac{1}{2}$ inches pitch, 2200 spindles. Production about 130 bundles, or 472 lbs. of No. 55's yarn per day.

III. Two systems of three cut line machinery for No. 40's to 120's (one for 40's to 70's, and one for 70's to 120's).
1 flax cutting machine.
1 P. Fairbairn and Co.'s patent double line of holder hackling machine.
2 spreaders or first drawing frames, 4 bosses each.
2 second drawing frames, 2 heads each, 6 slivers per head.
2 third drawing frames, 2 heads each, 8 slivers per head.
2 patent disc regulating roving frames, 72 spindles each, 12 spindles per head, 6 × $3\frac{1}{2}$ inches bobbin.
5 spinning frames, 220 spindles each, $2\frac{1}{2}$ inches pitch, = 1100 spindles.
5 spinning frames, 244 spindles each, $2\frac{1}{2}$ inches pitch, = 1220 spindles.
Production about 65 bundles or 236 lbs. of No. 53's yarn per day, and about 50 bundles or 105 lbs. of No. 95's yarn per day.

IV. Two systems of long tow machinery for No. 10's to 25's.
1 breaker card, 4 feet diameter, 6 feet wide, doffed by rollers.
1 lap machine.
2 finisher cards, 4 feet × 6 feet, with P. Fairbairn & Co.'s patent rotary gill drawing frames attached.
2 patent rotary gill drawing frames, 12 slivers each.
2 patent rotary gill disc regulating roving-frames, 48 spindles each, 8 inches × 4 inches bobbin.
3 spinning frames, 184 spindles each, 3 inches pitch for No. 10's to 18's = 552 spindles.
3 spinning frames, 200 spindles each, $2\frac{3}{4}$ inches pitch for No. 16's to 25's = 600 spindles.
Production about 39 bundles, or 488 lbs. No. 16's per day, and about 39 bundles or 312 lbs., No. 25's per day.

V. One system of cut tow machinery for No. 25's to 40's.
1 Breaker card, 4 feet diameter, 6 feet wide, doffed by combs.
1 Finisher card, with P. Fairbairn & Co.'s patent rotary gill drawing frame attached.
1 Screw gill second drawing frame, 3 heads each, 4 bosses per head.
1 Screw gill third drawing frame, 3 heads each, 6 bosses per head.
1 Screw gill patent disc regulating roving frame, 72 spindles, 12 spindles per head, 6 × $3\frac{1}{2}$ inches bobbins.
3 spinning frames of 220 spindles each; $2\frac{1}{2}$ inches pitch, = 660 spindles.
Production about 36 bundles, or 240 lbs. of No. 30's per day.

The reeling is generally carried on in the attic above the spinning room, and the number of reels required is about the same as the number of spinning frames.

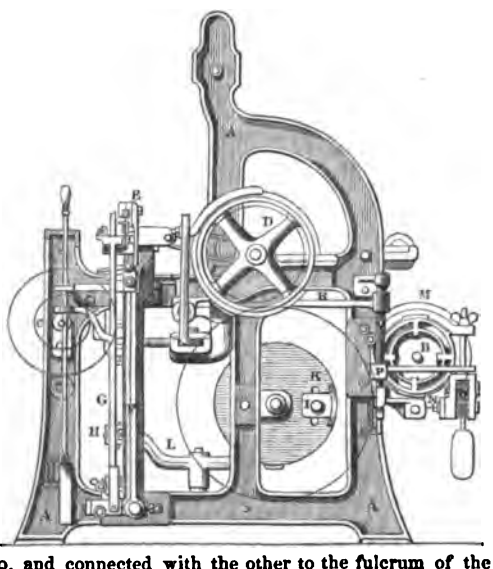
Summary view.

There are 3200 spindles long line, producing 196 bundles, or, 890 lbs. of yarn per day.

1152	„	long tow,	„	78	„	800	„
2320	„	3 cut line,	„	115	„	340	„
660	„	cut tow,	„	36	„	240	„
7332	spindles			425	bundles	2270	lbs. of yarn per day.

The waste in line spinning is generally about 10 per cent., and in tow spinning about 25 per cent.. so that the quantity of raw flax required to produce the above stated quantity of yarn would be about 20 cwts. of flax for long line and long tow spinning, and about 6 cwts. of flax for cut line and cut tow spinning.

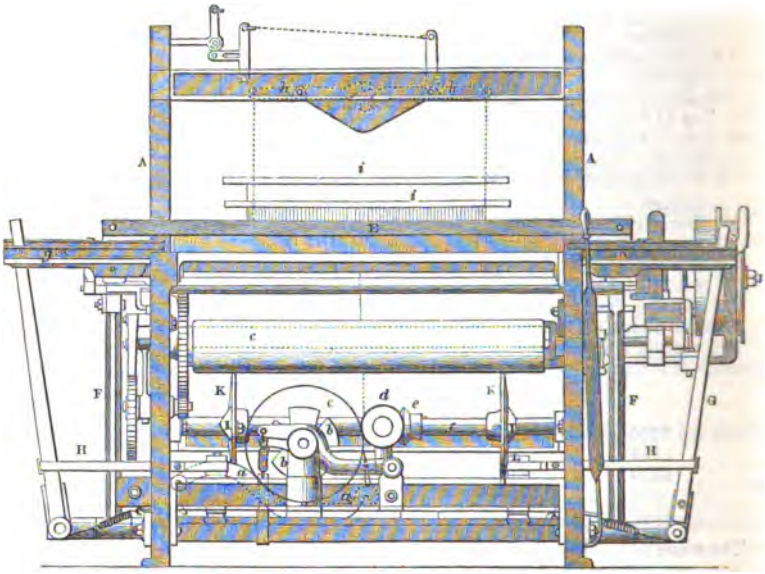
865



FLAX WEAVING LOOM FOR HEAVY FABRICS. — A A A, *figs.* 865, 866, frame of loom; B, beam on which the yarn for warp is wound; C, cloth receiving beam; D, driving pulleys and fly-wheel; E, hand rail for supporting the reed; F, swords of supports of going part; G, picking sticks for driving the shuttle; H leather straps for connecting the picking sticks with their actuating levers L; M, N, jaws of a clamp to cause the retaining friction on the collars of the beam B, by which friction the quantity of weft is regulated; O, end of lever, bearing the weight by which the jaws are brought together; P, lever, keyed at one end to the upright shaft Q, and connected with the other to the fulcrum of the weighted lever O; R, lever, one end of which is also keyed to the upright shaft Q, and the other is provided with a wood sole, and is pressed by a strong spring against the

yarn wound upon the beam B. It will be seen that, as the yarn is taken off the beam B, and its diameter consequently reduced, the lever P moves the fulcrum of the weighted lever O, and thus regulates the pressure upon the clamps M and N, causing an equal tension upon the yarn from the full to the empty beam; *a*, treddles, actuated by the cams *b*, driven by the wheels *c*, *d*, *e*, from the picking shaft *f*; *g g*, shuttle boxes at each end of the going part; *h h*, arrangement of levers to conduct equally

866



each end of the gears *i i*. This loom has also, in addition to the ordinary stopping arrangement connected with the shuttle, one also for relaxing the reed in case the shuttle should be arrested in its course across the warp, whereby the danger, ordinarily incurred by that accident, of breaking many threads in the warp, is avoided; it will also be seen that the bands called picking bands are superseded by the ends of the picking levers striking the shuttle direct; thus, by these improvements, drills are currently woven in this loom at the rate of 120 to 130 picks per minute.

Of late extensive trials have been made to adapt the power-loom to the weaving of light linen fabrics. Previously it had been found that while coarse and strong flax fabrics, such as those made at Dundee, Arbroath, &c., in Scotland, and the drills made at Barnsley, could be produced by power as well and more cheaply than by hand, yet that the lighter fabrics, such as shirtings, cambrics, lawns, &c., would not bear the strain of the power-loom, or at all events that to make them of as good appearance as by the hand-loom the manufacturer required to employ a dearer article of yarn, and so found that he could not compete with his neighbours who had hand-loom weavers. The scarcity of the latter in Ireland, during the last three or four years, and the advance in wages caused by the growing prosperity of the country, has directed the serious attention of the trade to the matter, and therefore manufacturers and machine makers have each zealously sought to remedy the defects that existed in the power-loom, as regards its application to the weaving of light linen fabrics, and to give repeated trials to new inventions. The consequence has been that, while four years ago there were only in Ireland fifty-two power-looms making linens of any kind, there are now nearly 3000, and these produce all kinds of flaxen fabrics of good quality, and fairly remunerative to the manufacturer. This branch of the manufacture is, however, as yet in an embryo state.

As respects other details of the subsequent processes which linens undergo before they are placed in the market, and also the general statistics of the entire trade in imports and exports, see BLEACHING, LINEN, &c. – J. M'A.

FLAX SEED. See LINSEED.

FLINT. (*Pierre à fusil*, Fr.; *Feuerstein*, Germ.) The fracture of this fossil is perfectly conchoidal, sometimes glossy, and sometimes dull on the surface. It is very hard, but breaks easily, and affords very sharp-edged splintery fragments; whence it is

a stone which strikes most copious sparks with steel. It is feebly translucid, has so fine and homogeneous a texture as to bear polishing, but possesses little lustre. Its colours are very various, but never vivid. The blackish-brown flint is that usually found in the white chalk. It is often white and opaque, loses its colour in the fire, and becomes greyish-white, and perfectly opaque. Flints occur almost always in nodules or tubercular concretions of various and very irregular forms. These nodules, distributed among the chalk, alongside of one another and almost in contact, form extensive beds; interrupted, indeed, by a multitude of void spaces, so as to present, if freed from the earthy matter in which they are imbedded, a species of network with meshes, very irregular both in form and dimension.

The nodules of silex, especially those found in the chalk, are not always homogeneous and solid. Sometimes there is remarked an organic form towards their centre, as a madrepore or a shell, which seems to have served as their nucleus; occasionally the centre is hollow, and its sides are studded over with crystals of quartz, carbonate of iron, pyrites, concretionary silex or calcedony, filled with pulverulent silica nearly pure, or silex mixed with sulphur; a very singular circumstance.

Flints are observed to be generally humid when broken immediately after being dug out of the ground; a property which disappears after a short exposure to the air. When dried they become more brittle and more splintery, and sometimes their surfaces get covered at old fractures with a thin film or crust of opaque silex

Flints calcined and ground to a powder enter into the composition of all sorts of fine pottery ware.

An important application of this siliceous substance was in the formation of gun-flints, for which purpose it was cut in a peculiar manner. The following characters distinguish good flint nodules from such as are less fit for being manufactured. The best are somewhat convex, approaching to globular; those which are very irregular, knobbed, branched, and tuberose, are generally full of imperfection. Good nodules seldom weigh more than 20 pounds; when less than 2, they are not worth the working. They should have a greasy lustre, and be particularly smooth and fine grained The colour may vary from honey yellow to blackish-brown, but it should be uniform throughout the lump, and the translucency should be so great as to render letters legible through a slice about one-fiftieth of an inch thick, laid down upon the paper. The fracture should be perfectly smooth, uniform, and slightly conchoidal; the last property being essential to the cutting out of perfect gun-flints. Although flint locks are now but rarely employed, the process of cutting the flints to shape possesses much interest.

Four tools are employed by the gun-flint makers.

First, a hammer or mace of iron with a square head, from 1 to 2 pounds weight, with a handle 7 or 8 inches long. The tool is not made of steel, because so hard metal would render the strokes too harsh, or dry, as the workmen say, and would shatter the nodules irregularly, instead of cutting them with a clean conchoidal fracture.

Second, a hammer with 2 points, made of good steel well hardened, and weighing from 10 to 16 ounces, with a handle 7 inches long passing through it in such a way that the points of the hammer are nearer the hand of the workman than the centre of gravity of the mass.

Third, the disc hammer or roller, a small solid wheel or flat segment of a cylinder, parallel to its base, only two inches and a third in diameter, and not more than 12 ounces in weight. It is formed of steel not hardened, and is fixed upon a handle 6 inches long, which passes through a square hole in its centre.

Fourth, a chisel tapering and bevelled at both extremities, 7 or 8 inches long, and 2 inches broad, made of steel not hardened; this is set on a block of wood, which serves also for a bench to the workmen. To these 4 tools a file must be added, for the purpose of restoring the edge of the chisel from time to time.

After selecting a good mass of flint, the workman executes the four following operations on it.

1. *He breaks the block.* Being seated upon the ground, he places the nodule of flint on his left thigh, and applies slight strokes with the square hammer to divide it into smaller pieces of about a pound and a half each, with broad surfaces and almost even fractures. The blows should be moderate, lest the lump crack and split in the wrong direction.

2. *He cleaves or chips the flint.* The principal point is to split the flint well, or to chip off scales of the length, thickness, and shape adapted for the subsequent formation of gun flints. Here the greatest dexterity and steadiness of manipulation are necessary; but the fracture of the flint is not restricted to any particular direction, for it may by chipped in all parts with equal facility.

The workman holds the lump of flint in his left hand, and strikes with the pointed hammer upon the edges of the great planes produced by the first breaking, whereby the white coating of the flint is removed in small scales, and the interior body of the

flint is laid bare; after which he continues to detach similar scaly portions from the clean mass.

These scaly portions are nearly an inch and a half broad, two inches and a half long, and about one-sixth of an inch thick in the middle. They are slightly convex below, and consequently leave in the part of the lump from which they were separated a space slightly concave, longitudinally bordered by two somewhat projecting straight lines or ridges. The ridges produced by the separation of the first scales must naturally constitute nearly the middle of the subsequent pieces; and such scales alone as have their ridges thus placed in the middle are fit to be made into gun-flints. In this manner the workman continues to split or chip the mass of flint in various directions, until the defects usually found in the interior render it impossible to make the requisite fractures, or until the piece is too much reduced to sustain the smart blows by which the flint is divided.

3. *He fashions the gun flints.* Five different parts may be distinguished in a gun-flint. 1. The sloping facet or bevel part, which is impelled against the hammer of the lock. Its thickness should be from two to three twelfths of an inch; for if it were thicker it would be too liable to break; and if more obtuse, the scintillations would be less vivid. 2. The sides or lateral edges, which are always somewhat irregular. 3. The back or thick part opposite the tapering edge. 4. The under surface, which is smooth and rather concave. And, 5. The upper face, which has a small square plane between the tapering edge and the back, for entering into the upper claw of the clock.

In order to fashion the flint, those scales are selected which have at least one of the above-mentioned longitudinal ridges; the workman fixes on one of the two tapering borders to form the striking edge, after which the two sides of the stone that are to form the lateral edges, as well as the part that is to form the back, are successively placed on the edge of the chisel in such a manner that the convex surface of the flint, which rests on the forefinger of the left hand, is turned towards that tool. Then with the disc hammer he applies some slight strokes to the flint just opposite the edge of the chisel underneath, and thereby breaks it exactly along the edge of the chisel.

4. The finishing operation is the *trimming*, or the process of giving the flint a smooth and equal edge; this is done by turning up the stone and placing the edge of its tapering end upon the chisel, in which position it is completed by five or six slight strokes of the disc hammer. The whole operation of making a gun-flint, which I have used so many words to describe, is performed in less than one minute. A good workman is able to manufacture 1000 good chips or scales in a day (if the flint balls be of good quality), or 500 gun-flints. Hence, in the space of three days, he can easily cleave and finish 1000 gun-flints without any assistance.

Flints form excellent building materials; because they give a firm hold to the mortar by their irregularly rough surfaces, and resist, by their nature, every vicissitude of weather. The counties of Kent, Essex, Suffolk, and Norfolk contain many substantial specimens of flint-masonry.

FLOCK and FLOCKS. The first is finely powdered wool, used when dyed of various colours to prepare paper hangings.

The second is a name given to the refuse or waste of cotton and wool, and is used for stuffing mattresses.

FLOCK PAPER. Paper prepared for walls by being sized in the first instance, either over the whole surface or over special parts, constituting the pattern only, and then powdering over it flock or powdered wool which had been previously dyed.

FLOOKAN or FLUKAN. The name given by the Cornish miners to veins filled wholly with clay. This is usually applied to such veins or lodes as are at right angles, or nearly so, to the true metalliferous lodes.

FLOOR CLOTH MANUFACTURE has become of late years a very large branch of trade. The cloth is a strong somewhat open canvas, woven of flax with a little hemp, and from 6 to 8 yards wide, being manufactured in appropriate looms, chiefly at Dundee. A piece of this canvas, from 60 to 100 feet in length, is secured tight in an upright open frame of oaken bars, in which position it is brushed over with glue size, and rubbed smooth with pumice stones; it next receives the foundation coats of paint, 2 or 3 in number, first on the back side, and then on the front. The foundation paint, made with linseed oil and ochre, or any cheap colouring matter, is too thick to be applied by the brush, and is therefore spread evenly by a long narrow trowel, held in the right hand, from a patch of it laid on just before with a brush in the left hand of the workman. Each foundation coat of the front surface is smoothed by pumice stone whenever it is hard enough to bear the operation. When both sides are dry, the painted cloth is detached from the frame, coiled round a roller, and in this state transferred to the printing room, where it is spread flat on a table, and variously figured and coloured devices are given to it by wooden blocks, exactly as in the block

printing of calicoes or papers. The blocks of the floor cloth manufacture are formed of two layers of white deal and one of pear tree timber, placed with their grain crossing one another alternately. There is a block for each colour in the pattern, and in each block those parts are cut away that correspond to the impressions given by the others; a practice now well understood in the printing of two or more colours by the press. The faces of the blocks are so indented with fine lines, that they do not take up the paint in a heavy daub from the flat cushion on which it is spread with a brush, but in minute dots, so as to lay on the paint (somewhat thicker than that of the house painter) in a congeries of little dots or teeth, with minute interstices between. Applied in this way, the various pigments lie more evenly, are more sightly, and dry much sooner than if the prominent part of the block which takes up the colour were a smooth surface. The best kinds of floor cloth require from two to three months for their production.

From the use of the sulphate of barytes with the white lead, sometimes to the extent of 75 per cent. of the former, not merely in the foundation paint, but in the subsequent colours with which the canvas is painted, there is a very general complaint that the floor cloths for halls, &c., where they are necessarily exposed to washing, very soon lose their colours and become bare, the barytes washing out, and, of course, removing at the same time the lead and other colours. See WHITE LEAD.

FLORAN. A mining term; tin ore scarcely perceptible in the stone; tin ore stamped very small.—*Pryce.*

FLOSS, of the puddling furnace, is the fluid glass floating upon the iron produced by the vitrification of the oxides and earths which are present. See IRON.

FLOSS-SILK (*Filoselle, Bourre de soie, fleuret,* Fr.) is the name given to the portions of ravelled silk broken off in the filature of the cocoons, which is carded like cotton or wool, and spun into a soft coarse yarn or thread, for making bands, shawls, socks, and other common silk fabrics. The floss or fleuret, as first obtained, must be steeped in water, and then subjected to pressure, in order to extract the gummy matter, which renders it too harsh and short for the spinning-wheel. After being dried it is made still more pliant by working a little oil into it with the hands. It is now ready to be submitted to the carding engine, and it is spun upon the flax wheel.

The female peasants of Lombardy generally wear clothes of homespun floss silk. Of late years, by improved processes, fine fabrics of this material have been produced, both in England and France. M. Ajac, of Lyons, manufactures a variety of scarfs and square shawls of *bourre de soie,* closely resembling those of *cachemire.*

FLOUR. The finely ground meal of wheat, and of any other corns or *cerealia.* See BREAD.

Since the analyses of grains represent the total chemical constituents of the flour, and the cell in which it is contained, a few analyses from the researches of Way and Ogston are given: —

	Wheat.			Barley.		
	Hopeton.	Red Straw.	Old Red Lammas.	Chevalier.	Unknown.	Moldavia.
Potassa	30·32	29·75	32·46	27·43	21·14	31·55
Soda	0·07	0·64	4·53	0·05	- -	1·06
Lime	2·51	3·27	3·21	2 79	1·65	1·21
Magnesia	12·38	13·75	9·56	8·67	7·26	10·17
Sesquioxide of iron	0·08	0·23	2·06	0·09	2·13	1·02
Sulphuric acid	0·18	0·60	0·32	2·72	1·91	0·27
Silica	3·60	2·14	5·46	23·60	30·68	24·56
Phosphoric acid	49·22	49·58	40·57	26·01	28·53	28·64

The produce of one quarter of wheat weighing 504 lbs. is, according to Mr. Hard of Dartford —

Flour	392 lbs.
Biscuit or fine middlings	10
Toppings or specks	8
Best pollard	15
Fine pollard	18
Bran and coarse pollard	50
Loss	11
	504 lbs.

Vauquelin has given the following as the results of his examination of wheat flour : —

	French.	Odessa hard.	Odessa soft.	Paris flour.	Inferior flour.
Starch - - - - -	71·49	56·5	62·00	72·8	67·78
Gluten - - - - -	10·96	14·55	12·00	10·2	9·02
Sugar - - - - -	4·72	8·48	7·56	4·2	4·80
Gum - - - - -	3·82	4·90	5·80	2·8	4·60
Bran - - - - -	- -	2·30	1·20	- -	- -
Water - - - - -	10·00	12·00	10·00	10·0	12·00

Adulterations of, to detect. — The first method is by specific gravity. If potato flour be added, which is frequently done in France, since a vessel which contains one pound of wheat flour will contain one pound and a half of the fecula, the proportion of this adulteration may be easily estimated. If gypsum or ground bones be mixed with the flour, they will not only increase its density still more ; but they will remain after burning away the meal as ashes.

The second method is by ascertaining the quantity of gluten which the suspected sample will afford, see the article BREAD. The two following chemical criteria may also be employed.

1st. Nitric acid has the property of colouring wheat flour of a fine orange yellow, whereas it affects the colour neither of fecula nor starch.

2nd. Muriatic acid colours good wheat flour of a deep violet, but dissolves fecula or starch, and forms with it a light and colourless viscous fluid, decomposable by alkalies.

Sulphate of iron renders an infusion of pure flour somewhat yellow, and imparts a bottle green to that which is adulterated with bean meal. — (*Lassaigne.*) Nitric acid and ammonia poured successively on good flour shows nothing remarkable ; but bean meal strikes a deep red colour. — (*Donny.*)

The amount of ash left by the flour has been proposed by Louyet as a test of its purity. He says, " Wheat flour yields on the average 0·8 per cent. ; rye flour, 1·0 ; bean and pea meal, 3 ; linseed meal, 10 per cent. of ash."

FLOWERS. The name formerly given to those substances which were obtained by sublimation ; as the flowers of sulphur, the flowers of Benjamin, &c.

FLOWERS, ARTIFICIAL, MANUFACTURE OF. The art of representing by flowers, leaves, plants, &c., vegetable nature in her ornamental productions, constitutes the business of the artificial florist. The Italians appear to have been the first people in Europe who excelled in the art of making artificial flowers ; but of late years the French have been most ingenious in this branch of industry.

Ribbons folded in different forms and of different colours were originally employed for imitating flowers, by being attached to wire stems. This imitation soon gave way to that by feathers, which are more delicate in texture, and more capable of assuming a variety of flower-like figures. But a great difficulty was encountered in dyeing them with due vivacity. The savages of South America manufacture perfect feather flowers, derived from the brilliant plumage of their birds, which closely resemble the products of vegetation. The blossoms and leaves are admirable, while the colours never fade.

The Italians employ frequently the cocoons of the silk-worm for this purpose ; these take a brilliant dye, preserve their colour, and possess a transparent velvety appearance, suitable for petals. Of late years, the French have adopted the finest cambric for making petals, and the taffeta of Florence for the leaves. M. de Bernardiere employs whalebone in very thin leaves for artificial flowers ; and by bleaching and dyeing them of various hues, he has succeeded in making his imitations of nature to be very remarkable.

Gutta percha dissolved in benzole, and freed from all impurities, will when spread out on a sheet of glass dry into a beautifully white and delicate film, of great strength, and capable of receiving any colour. This has been employed in Paris in the manufacture of flowers. Vegetable parchment (paper prepared by the action of sulphuric acid) has been employed for the same purpose in this country. See VEGETABLE PARCHMENT.

The colouring matters used in flower dyeing are the following : —

For red ; carmine dissolved in a solution of carbonate of potash.

For blue ; indigo dissolved in sulphuric acid, diluted and neutralised in part by Spanish whitening.

For bright yellow ; a solution of turmeric in spirit of wine. Cream of tartar brightens all these colours.

For violet; archil, and a blue bath.

For lilac; archil.

Some petals are made of velvet, and are coloured merely by the application of the finger dipped in the dye.

FLUATES, more properly *fluorides*. (Eng. and Fr.; *Flussdure*, Germ.) Compounds of fluorine and the metals; as fluor spar, for example, which consists of fluorine and calcium.

Fluor spar consists of —	
Fluorine	48·7
Calcium	51·3
Cryolite —	
Fluorine	54·2
Sodium	32·8
Aluminium	13·0
Chiolite —	
Fluorine	57·53
Sodium	23·78
Aluminium	18·69

Fluellite is fluorine and aluminium, a rare mineral found at Stennagwyne in Cornwall.

FLUKES. See ANCHOR.

FLUORESCENCE, the name given to a peculiar phenomenon rendered evident by many crystals of fluor spar. If we look through a crystal of fluor spar it will appear yellow or green as the case may be; now if we look at it, the light falling upon the surface on which we look, it will appear beautifully blue or purple. Mr. Stokes, to whom we are indebted for a very exact examination of the whole of the phenomena of this class, refers this effect to an alteration of the refraction of the ray by the first surface upon which it falls. Sir John Herschel first drew attention to this peculiar condition as exhibited in a solution of sulphate of quinine in water slightly acidulated with sulphuric acid. Here we have a perfectly colourless solution when we look through it, which sends back to the eye fine blue rays when we look at the surface on which the solar rays fall. Sir John Herschel referred this to epipolic dispersion, or dispersion from the first surface of the fluid on which the light fell. There are many substances which appear to possess this property of altering the refraction of rays, or are fluorescent. Beyond this brief explanation, we cannot afford space in this dictionary to deal with the subject. We must refer those interested to the Philosophical Transactions, in which Mr. Stokes's communications appeared.

FLUORINE. The elementary base of fluoric acid, which has never yet been isolated.

The power of liberating a principle from fluor spar, which would etch glass was known as far back as 1670; Scheele, in 1771, examined fluoric acid, and regarded it as an oxygen compound with an unknown element. Ampere, in 1810, determined the fluoric acid was a compound of hydrogen and fluorine.

Fluorine combines with most of the metals, and with hydrogen, boron, silicon, sulphur, and phosphorus; with chlorine, bromine, iodine, and oxygen it exhibits no tendency to unite.

Symbol, F; equivalent, 19.

FLUOR SPAR. (*Chaux fluatée*, Fr.; *Spath fluor*, Germ.) This mineral often exhibits a variety of vivid colours. It crystallises in the cubic (monometric) system, with regular octahedral and tetrahedral cleavages; spec. grav. 3·14 to 3·19; H = 4·0; scratches calc spar, but is scratched by a steel point; usually phosphorescent with heat; at the blowpipe decrepitates and fuses into an opaque bead; acted on by the acids with disengagement of a vapour which corrodes glass; its solution affords precipitates with the oxalates, but not with ammonia. Its constituents are, fluorine, 48·7; calcium, 51·13 in 100.

Fluor spar occurs subordinate to metallic veins; as to those of lead, in Derbyshire and Cumberland; of tin and copper, in Cornwall, and in Saxony and Bohemia; but it is found also in masses or veins, either in crystalline rocks, associated with quartz, barytes, &c., as in Auvergne, Forez, Vosges, Norberg in Sweden; Norway; Petersburg; Gourock, in Scotland, &c.; or among secondary limestones, slates, and sandstones, in Derbyshire, Cumberland, Cornwall, and New Jersey. It exists also in the amygdaloids of Scotland, and in the volcanic products of Monte Somma at Vesuvius. The variously coloured specimens, called Derbyshire spar, are worked upon the turning lathe into vases and other ornamental objects.

A very beautiful variety, which has been much used for ornamental purposes, known from its colour as "Blue John," has been obtained from Tray Cliff near

Castleton, Derbyshire. The beautiful colour of the natural fluor has been successfully imitated by exposing some of the common varieties to heat.

Fluor spar is employed to a considerable extent in the production of hydrofluoric acid and for etching on glass. It is also used by lead smelters as a flux. The beautiful phenomenon of *fluorescence* is so named from the fact that many of the fluor spars have the power in a high degree of thus affecting the rays of light. See FLUORESCENCE.

FLUVIATILE (*fluvius*, a river), belonging to a river.

FLUX (Eng. and Fr.; *Fluss*, Germ.) signifies any substance capable of promoting the fusion of earths or metallic ores by heat. White flux is the residuum of the deflagration, in a red hot crucible, of a mixture of two parts of nitre and one of cream of tartar. It is in fact merely a carbonate of potash. Black flux is obtained when equal parts of nitre and tartar are deflagrated. It owes its colour to the carbonaceous matter of the tartaric acid, which remains unconsumed; the quantity of nitre being too small for that purpose. The presence of the charcoal renders this preparation a convenient flux for reducing calcined or oxidised ores to the metallic state. Limestone, fluor spar, borax, and several earthy or metallic oxides, are employed as fluxes in metallurgy. See METALLURGY.

FLY POWDER. Under this name they sell on the continent the black coloured powder obtained by the spontaneous oxidisement of metallic arsenic in the air. Various preparations of white arsenic are used for the same purpose in this country. King's yellow is much used; it should be made by boiling together sulphur, lime, and white arsenic, but much that is sold is merely arsenic and sulphur mixed.

Objecting on principle to the familiar use of arsenic and dangerous substances, a preference may be given to a substitute for the above, made by boiling quassia chips into a strong decoction and sweetening with loaf sugar. This seems to have deadly power over the flies, who can scarcely quit the liquid without imbibing a deadly potion, and they are seen to fall from the ceilings and walls of the rooms soon afterwards. Many of these compounds for killing flies are supposed by their odour to attract flies into the rooms.

The inconvenience to manufacturers and others from flies, may be obviated in many cases where apartments are required to be kept as free as possible from them, by reference to facts recorded by Herodotus, of fishermen surrounding themselves with their nets to keep off the gnats. We are indebted to William Spence, Esq. F.R.S., for some very curious particulars respecting the common house fly communicated in a paper to the Entomological Society. The common house fly, will not in general pass through the meshes of a net. The inhabitants of Florence and other parts of Italy are aware of this fact, and protect their apartments by hanging network up at the windows, thus at all times the doors and windows may be kept wide open by hanging a light network over the aperture; the meshes may be of considerable width, say enough for several flies on the wing to pass through, and no fly will attempt to pass, unless there be a strong light (another window opposite, or reflection from a looking-glass). A knowledge of this simple means of protection from flies on the wing may prevent inconvenience from these intruders, and obviate the necessity for poisons to destroy them.—T. J. P.

FODDER, is the name of a weight by which lead and some other metals were sold in this country; but it is now rarely used. It varied in its amount in different parts of the kingdom, being 19½ cwts. at Hull; 21 cwts. at Newcastle; 22 cwts. at Stockton; 24 cwts. in Derbyshire.

FOILS. Thin sheet copper silvered and burnished, and afterwards coated with transparent colours mixed with isinglass, employed by jewellers to improve the brilliancy of pastes and inferior stones. The foil is inclosed in the setting, and entirely covers the back of the stone, to which it imparts much of its own brilliancy.

FOILS. Thin leaves of metal, usually alloys, of various colours, employed principally for heightening the brilliancy of artificial gems.

FONDUS, is the name given by the French to a particular style of calico printing resembling the rainbow, in which the colours are graduated or melted (*fondus*) into one another, as in the prismatic spectrum. See CALICO PRINTING for a description of the process.

FOOD. See NUTRITION.

FOOTWALL, *a mining term*. The "wall" or side of the rock under the mineral vein: it is as commonly called the *underlaying wall*.

FOOTWAY, *a mining term*. The ladders by which the miners descend and ascend.

FORGE (Eng. and Fr.; *Feuer*, Germ.) is the name either of the furnace, where wrought iron is hammered and fashioned with the aid of heat, or the great workshop where iron is made malleable. The former is called a smith's forge, the latter a shingling mill. See IRON.

Fig. 867 represents a portable truck forge of a very commodious construction. A is the cylindric leather bellows, pressed down by a helical spring, and worked by means of the handle at B, which moves the horizontal shaft C, with its two attached semicircular levers and chains. D is the pipe which conducts the blast to the nozzle at E. The hearth may be covered with a thin fire-tile or with cinders. F is a vice fixed to the strong rectangular frame. This apparatus answers all the ordinary purposes of a smith's forge; and is peculiarly adapted to ships, and to the execution of engineering jobs upon railways, or in the country. The height is 2 feet 6 inches; the length is 2 feet 9 inches; the width 2 feet. Weight about 2 cwt.

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Holtzapffel describes another portable forge of his own construction, possessing many advantages.

With the manipulations of the forge, it is not the province of this work to deal.

FORK, *a mining term.* A mine is said to be "in fork," or an engine to have the "water in fork," when all the water is drawn out.

FORMATION. A geological term, which is used to signify a group of rocks, referred to a common origin, or belonging to the same period.

FORMIATES. Compounds with formic acid. See *Ure's Dictionary of Chemistry.*

FORMIC ACID. (*Acidè Formique*, Fr.; *Ameisansaure*, Germ.) The acid which exists in the bodies of ants, associated with malic acid.

Formic acid was obtained artificially, originally by Fisher of Leeds in 1670, and subsequently by Dr. Hulse, by distilling red ants.

It may be prepared by boiling 1 part of starch with 4 of sulphuric acid, and 4 of water, allowing the liquor to cool, and adding gradually 4 parts of the black oxide of manganese and distilling. For the reactions which take place see *Ure's Chemical Dictionary.* Its formula is C^2HG^3HO. It is a clear colourless fluid, which crystallises below 32° into brilliant plates.

FORMULÆ, CHEMICAL. See EQUIVALENTS.

FORMYLE. The hypothetical base of formic acid.

FOSSIL (*fossilis*, anything dug from the earth). Formerly all minerals were called fossils, but the word is now restricted to express the remains of animals and plants found buried in the earth.

FOSSIL IVORY. The bones and tusks of elephants and mammoths are found in eastern Siberia, and along the shores of the Arctic sea, in great abundance. The tusks are collected for sale, but it is much less valuable than the recent ivory.

FOUNDING. In foundries attached to blast-furnaces, where from 20 to 30 tons of iron are made *per diem*, the moulds are generally mere troughs cut in the sand into which the melted metal flows and cools in contact with the air. The surfaces of the castings made in this manner present appearances which vary according to the quality of the iron.

The kinds of iron adapted for founding purposes are those which are most fluid when melted, and which contain most carbon, and are called Nos. 1 and 2. They are distinguished by the surface of the pig of iron, which was exposed to the air during cooling, being smooth, and presenting a slightly convex figure. The surfaces of Nos. 3 and 4 pig-iron, and of the white crystalline pig-iron (most suitable for making into wrought iron) present a concave figure, and the surfaces are very irregular and pitted with holes. The colour of the fracture, and the closeness of the grain, also indicate the proportion of carbon in pig-iron.

The mixtures of metal, melting temperatures of metal, &c., require the closest observation on the part of the workmen and foremen who practice iron founding, and these mechanics are in the practice of observing differences so minute that they cannot be appreciated by the chemist, or expressed in words.

Machinery has enabled the modern founder, by means of railways, turn-tables,

travelling-cranes, and steam-power, to move at will the heaviest masses without confusion and with great expedition; but nothing but the traditions of the factory, and the constant habit of observation will enable him to conduct properly the melting and casting of metal so as to arrive at certain results.

This is proved by the constant failures of those who undertake to make descriptions of castings, of which they have had no previous knowledge.

Each branch of foundry work must be studied in detail, and we can only pretend to indicate those directions in which progress has been and is being made.

FOUNDRY.—The process of iron smelting and the construction of furnaces having been described under other heads, the remaining part of the business of a foundry, viz., that which relates to the preparation of the moulds and moulding, will now be described.

Moulding.—The art of moulding is one of the most important processes carried on in a foundry, and the success of the founder is directly proportioned to the skill and ingenuity brought to bear upon the production of the patterns and the system of moulding.

Before metals can be cast into the variety of shapes in which they are wanted, patterns must be prepared of wood or metal, and then moulds constructed of some sufficiently infusible material capable of receiving the fluid metal, and retaining it without uniting with it until it has solidified.

A mixture of sand and loam (packed tightly into metal boxes, called flasks) is generally chosen as the material for making moulds, and is employed advantageously for several important reasons.

Flasks.—In modern foundries a system has been invented, by which flasks of any dimensions may be constructed by means of bolting together a number of rectangular frames of cast-iron, so arranged as to admit of being easily connected together.

When the particular castings for which the flask has been constructed, or rather compounded, are completed, the separate pieces are unbolted, and are ready to be combined in some new form appropriate to the dimensions of the pattern next to be moulded in them.

The loss of capital, &c., invested in flasks, only occasionally used, is thus saved, as well as loss of time in searching for the size required. The space devoted, on the old system, to the reception of flasks belonging to a foundry was very large, and this may now be appropriated to other purposes.

Sand and loam.—Founders formerly used, on account of price, the description of sand most accessible to them, but at the present time, the convenience and cheapness of railway carriage has enabled special qualities of sand to be delivered to all parts of England.

For founding purposes sand is much improved by the admixture of coke, crushed and reduced to a fine powder, and a mill for this purpose is as necessary in every large foundry as those for grinding and mixing loam.

Moulding sand must be a mixture of a large quantity of silex and a small quantity of alumina—the property of the latter material being to cement the grains of silex together. Loam consists of the same materials mingled in opposite proportions.

The preparation of loam for those purposes for which sand is not adapted, is an important duty in a foundry, for a great quantity of loam cores have to be made and dried in proper ovens, which is a tedious operation.

Many castings, such as the screws for steamers, are more conveniently cast in moulds constructed of wet loam. These are shaped to the required form when the clay is moist, and then carefully dried afterwards.

Other castings are of such peculiar shapes that they can only be produced in moulds that take in a vast number of pieces. These moulds are then formed of a number of pieces of hardened sand, held together by strips of iron or of plaster, if the sand used is not coherent enough of itself.

Compounds of silex and alumina are very infusible, and when moistened with water and faced with carbonaceous matter, they are capable of receiving the most delicate impressions from the patterns which the founder employs.

Grains of sand are so irregular in shape themselves that they leave innumerable irregular spaces between them, and these intervals form a net work of channels which permit the rapid escape of the gases, which are so violently generated by the contact of hot metal falling upon wet sand.

Machine Castings.—Every year, engineers order castings to be prepared of more difficult and complicated forms, and with greater perfection of surface then they have required before.

The reason of this is, that with the progress of the mechanical arts larger and stronger machines are continually being introduced. In these machines greater steadiness of cast-iron frame work is necessary, than can conveniently be obtained when the frame is made out of a number of pieces of iron cast separately and then bolted together. It would be impossible to mould large frames with pieces projecting on all sides (prepared to receive the moving parts of the machines), and jutting out

in contrary directions, in any flasks filled with wet sand, for the pattern never could be removed without destroying the impression. To meet these difficulties the modern ironfounder has had to follow those plans which were first proved practicable by those who have devoted themselves to casting bronze statues. In founding, as in so many other branches of manufacture, the discoveries made in prosecuting the fine arts have been advantageously adopted by those engaged in works of utility.

False Cores.—The introduction of the drawbacks, or false cores, made of sand pressed hard (and admitting of taking to pieces by joints, at each of which a layer of parting sand is prepared), used for figure casting, enables the moulder to work at his leisure, without fearing that his mould may tumble to pieces, and also enables him to fashion these drawbacks or cores into the most complicated forms, with the power to remove them while the pattern is removed, and build them up again round the empty space (formerly occupied by the pattern) with the greatest facility and accuracy.

The workmen, whose occupation is to knead the sand into the forms required by the founder, are termed moulders, and they form a very numerous body of mechanics, demanding and receiving high wages.

The moulder has often only his sand, his flasks, cranes, and a few simple tools (for smoothing rough places, and for repairing the places in the sand where the mould has broken away during the lifting of the pattern); he has to make proper arrangements for the exit of the atmospheric air which leaves the mould as the fluid metal takes its place; and he is expected to produce an exact copy in metal from any pattern, simple or complicated, which may be brought before him.

It will be evident that to produce a good result with such imperfect appliances as the ordinary moulder uses, a skilful workman must be employed, and time expended in proportion to the difficulty of the operations to be performed.

Where only a few impressions from a model are required, it is not worth while to spend money in making expensive patterns, or providing those appliances which may enable patterns to be moulded with facility and little skill; but where thousands of castings are wanted of one shape, it is expedient to spend money and skill on patterns and tools, and reduce the work of the moulder to its minimum.

Management.—The best managed foundry is not that in which good castings are obtained by the employment of skilled workmen at a great expense, and without trouble or thought on the part of the principal, but rather that in which the patterns have been constructed with a special reference to their being cast with the minimum of skill and the maximum of accuracy. It is only by the forethought and calculation of the manager that subsequent operations can be reduced to their smallest cost; and in the foundry, as in all other manufactories, the true principles of economy are only practised where the head work of one person saves the manual labour of a large number.

Improvements.—The attention of founders has been turned—1st, to the methods by which the labour of making moulds in sand might be reduced; 2nd, to the introduction of improvements in the mode of constructing patterns and moulds; and 3rd, to the manufacture of metallic moulds for those purposes for which they could be applied. A great progress has been made during the last twenty years in these different directions.

Machine Moulding.—In the large industry carried on for the production of cast-iron pipes for the conveyance of water and gas, machinery has been applied so that the operation of pipe-moulding is performed almost without manual labour, with great rapidity and precision. The cost of pipes at the present time is only about 2*l.* per ton above the value of pig-iron, out of which they are made. A sum very small when it is considered that the iron has to be re-melted, an operation involving both a cost of fuel and a loss of 5 to 20 per cent. of the iron in the cupola. An ingenious machine for moulding in sand, spur and bevel wheels of any pitch or diameter has been employed in Lancashire; the advantage being that the machine moulding-tool acts directly upon the sand without the intervention of any pattern or mould. In any large foundry there is an enormous accumulation of costly wheel-patterns, taking up a great deal of space, and these can now be dispensed with by substituting the wheel moulding-machine. Railway chairs are moulded in a machine; and plough shares, which although only weighing a few pounds each, are sold at the low rate of 8*l.* a ton, are moulded in a machine.

Plate Casting.—Under the next class of improvements the introduction of plate-casting has been the most fruitful of good results.

One great source of expense and trouble in a foundry is the injury done to patterns and to their impressions in the sand by the necessity, under the ordinary system of moulding, of striking the pattern, or pushing it first in one direction and then in another in order to loosen it. Now, the object of the machinist is to construct all his spindles, bearings, bolts, and wheels, of specified sizes, and then to cast the framing of his machine so accurately that the working parts may fit into the frame without any manual labour. In order to effect this, every projection and every aperture in

the casting must be at an exact distance, and this can only be attained by employing such a system as that of plate-casting, where the pattern is attached firmly to a plate, and it is impossible for the moulder to distort or injure the impression. Plate-casting has been long known, but was practically confined for many years to the production of small articles, such as cast nails and rivets.

In a plate-mould for rivet-casting, the shafts of the rivets are attached to one side of the plate, which is ¾-in. thick, and planed on both sides. The heads of the rivets are on the opposite side of the plate. The guides on the upper and lower flask admit the plate to fit between them, and when the plate is withdrawn the upper and lower flask close perfectly, and are in all respects like ordinary moulders' flasks. The principle of moulding is very simple, and can be performed without skilled

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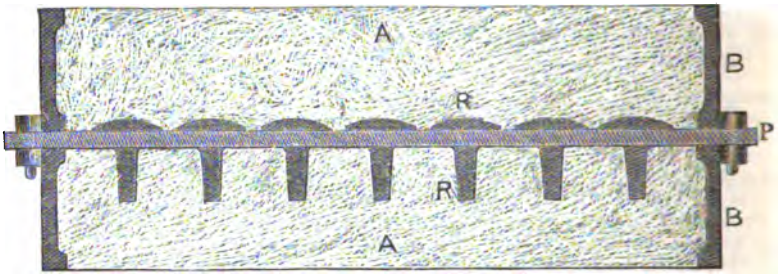

A, sand. B B, flask. R R, rivet pattern. P, plate.

labour ten times as fast as ordinary moulding, and with far greater accuracy. The plate is inserted between the upper and lower flasks, and sand is filled in; the plate is then withdrawn by simply lifting it; the guides prevent any shaking in this operation; when the flasks are closed the impression of the head of each rivet is exactly perpendicular to its shaft. The first expense of patterns and plates of this description is large, but the accuracy and rapidity of the process of moulding is so advantageous as to cause us to look to the applications of plate-castings becoming very extensive, since the requirements of the machine-maker demand every year better castings at lower prices.

When both sides of a pattern are symmetrical one half only need be attached to the smooth plate, the other face of the plate being left blank. An impression of the pattern must be taken off both in the upper and lower flask, and when these are united the result will be the same as if both sides of the plate had been moulded from. For unsymmetrical patterns both sides of the plate must be employed. The system of using plates with apertures in them, through which patterns could be pushed and withdrawn by means of a lever, was first employed in casting brass nails. A modification of this system has been extensively employed at Woolwich for moulding shot and shells, in the following manner: —

Shell Casting. — A circular aperture is made in a horizontal planed plate of iron, two inches thick. Through this a sphere of iron, of the same diameter as the aperture, is pushed until exactly a hemisphere appears above the plate. The lower flask is put on to the plate, and sand filled in; the lever being relieved the sphere falls by its own weight; the lower flask is removed and the upper flask put on the plate; the sphere is pushed through the plate as before, sand filled in, with great rapidity and accuracy.

The sand cores for filling up that part of the shell which is to be hollow are also carefully and quickly made at Woolwich. The halves of the core-mould, open and shut with a lever, so that the bad plan of striking the core-mould is avoided as completely as the bad plan of striking the pattern is in the process of moulding shot and shell.

Theory of Casting.—Before leaving the subject of the use of sand moulds, we may remark that iron and brass castings with a perfect surface can only be produced when the mould is well dried and heated, so as to drive out any moisture from the apertures between the grains of sand. By this means channels are opened for the rapid escape of the heated air and gas expelled by the entrance of the fluid metal into the mould, and the surface of the metal is not cooled by its contact with damp or cold sand. It is also well to mix charcoal dust, or coke dust, with the sand; and for fine castings to cover the surface of the sand with a coating of charcoal dust. The object of this proceeding is to reduce the oxide which may be present in the metal. This operation of reducing the oxide of a metal instantaneously is performed with the greatest certainty by this simple means, invented, probably, by the earliest metallurgists. By

incorporating a quantity of charcoal or coke-dust with the sand, or facing the sand with carbonaceous matter, any oxide of the metal which may be floating amongst the pure metal is at once reduced. Sand (being a non-conductor) does not abstract the heat from the fluid metal rapidly, and, therefore, solidification of the metal takes place comparatively regularly and equally throughout the mass; when one part of the casting solidifies before the adjoining part, flaws often occur, and to avoid these the skill of the practical founder is necessary in arranging for the entrance of the metal at the proper point, and for the exit of the air.

We next proceed to the third class of improvements in moulding, that of the extension of the application of metallic moulds.

Metal Moulds.—The practice of casting bronze weapons in moulds made of bronze (blackened over on their surface to prevent the fluid metal uniting with the mould) appears to have been a very general one among the ancients.

Some moulds of this description have been discovered amongst the Celtic (?) remains disinterred in different parts of Europe.

The facility for the escape of the heated air and gases from the sand moulds into which liquid metal is poured, is so much greater than that from moulds of metal, that at the present time neither brass nor iron is poured into metallic moulds, except when a particular purpose is to be attained, viz., that of chilling the surface of the iron and making it as hard as steel. Iron cannot be chilled or hardened in a sand mould.

Chilled Iron.—This process of casting in metal moulds was once supposed to be a modern invention; but it now appears, from the metal moulds discovered among the remains of the Celtic race throughout Europe, that the bronze weapons of the people who preceded the Romans were generally cast in metallic moulds, and not in sand. Chilled castings have been brought to great perfection by Messrs. Ransome, of Ipswich. Their chilled ploughshares and chilled railway chairs are cast in moulds of such a construction that the melted iron comes in contact with iron in those parts of the moulds where it is wanted to be chilled. A section of the casting shows the effect of chilling.

Zinc.— In casting zinc (a cheap and abundant metal), which fuses at a low temperature, metallic moulds may be most advantageously used. It is, however, necessary to heat the iron or brass mould nearly to the temperature of melting zinc, in order that the rapid abstraction of heat from the fluid metal may be prevented. The preparation of metal moulds, and the casting soft metal in them is now an extensive and important industry on the Continent, for ornamental zinc castings have suddenly come into extensive use in consequence of the discovery of the electrotyping process. When covered with a thin coating of brass or copper by a galvanic battery, zinc may be bronzed so as to present almost the exact external appearances of real bronze at a tenth of the cost.

When metal moulds are used their first cost is very great, as they must be made in numerous separate pieces so as to liberate the castings. The joints and ornaments have to be chased and accurately fitted at a great expense. Their use, however, requires no skill in the workman, and the rapidity with which the zinc is cast, the mould taken to pieces, and the casting removed, renders the operation a very rapid and economical one.—A. T.

Such is a general view of the practice of founding. The details, however, which are contained in the original article in the last edition of this dictionary, appear so valuable that that article is retained in addition to the above.

The essential parts of a well-mounted iron foundry, are,

1. Magazines for pig irons of different qualities, which are to be mixed in certain proportions, for producing castings of peculiar qualities; as also for coal, coke, sands, clay, powdered charcoal, and cow-hair for giving tenacity to the loam mouldings.

2. One or more coke ovens.

3. A workshop for preparing the patterns and materials of the moulds. It should contain small edge millstones for grinding and mixing the loam, and another mill for grinding coal and charcoal.

4. A vast area, called properly the foundry, in which the moulds are made and filled with the melted metal. These moulds are in general very heavy, consisting of two parts at least, which must be separated, turned upside down several times, and replaced very exactly upon one another. The casting is generally effected by means of large ladles or pots, in which the melted iron is transported from the cupola where it is fused. Hence the foundry ought to be provided with cranes, having jibs movable in every direction.

5. A stove in which such moulds may be readily introduced, as require to be entirely deprived of humidity, and where a strong heat may be uniformly maintained.

6. Both blast and air furnaces, capable of melting speedily the quantity of cast-iron to be employed each day.

7. A blowing machine to urge the fusion in the furnaces.

Fig. 869, represents the general plan of a well-mounted foundry.

a, is a cupola furnace; it is capable of containing 5 tons of cast-iron.

a', is a similar furnace, but of smaller dimensions, for bringing down 1¾ tons.

a'', is a furnace like the first, in reserve for great castings.

b b b b, a vast foundry apartment, whose floor to a yard in depth, is formed of sand and charcoal powder, which have already been used for castings, and are ready for heaping up into a substratum, or to be scooped out when depth is wanted for the moulds. There are besides several cylindrical pits, from five to seven yards in depth, placed near the furnaces. They are lined with brick work, and are usually left full of moulding sand. They are emptied in order to receive large moulds, care being had that their top is always below the orifice from which the melted metal is tapped.

These moulds, and the ladles full of melted metal are lifted and transported by the arm of one or more men, when their weight is moderate; but if it be considerable,

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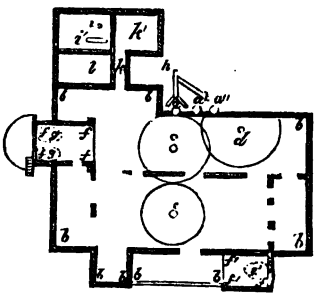

they are moved about by cranes, whose vertical shafts are placed at *c*, *d*, *e*, in correspondence, so that they may upon occasion transfer the load from one to another. Each crane is composed principally of an upright shaft, embraced at top by a collet, and turning below upon a pivot in a step; next of a horizontal beam, stretched out from nearly the top of the former, with an oblique stay running downwards, like that of a gallows. The horizontal beam supports a movable carriage, to which the tackle is suspended for raising the weights. This carriage is made to glide backwards or forwards along the beam by means of a simple rack and pinion mechanism, whose long handle descends within reach of the workman's hand.

By these arrangements in the play of the three cranes, masses weighing five tons may be transported and laid down with the greatest precision upon any point whatever in the interior of the three circles traced upon *fig.* 869, with the points *c*, *d*, *e*, as centres.

c, *d*, *e*, are the steps, upon which the upright shafts of the three cranes rest and turn. Each shaft is 16 feet high.

f f, is the drying stove, having its floor upon a level with that of the foundry.

f' f', is a supplementary stove for small articles.

g g g', are the coking ovens.

h is the blowing machine or fan.

i, is the steam-engine, for driving the fan, the loam-edge stones,

k, and the charcoal mill.

i', are the boiler and the furnace of the engine.

k', workshop for preparing the loam and other materials of moulding.

l, is the apartment for the patterns.

The pig-iron, coals, &c., are placed either under sheds or in the open air, round the above buildings; where are also a smith's forge, a carpenter's shop, and an apartment mounted with vices for chipping and rough cleaning the castings by chisels and files.

Such a foundry may be erected upon a square surface of about 80 yards on each side, and will be capable, by casting in the afternoon and evening of each day, partly in large and partly in small pieces, of turning out from 700 to 800 tons per annum, with an establishment of 100 operatives, including some moulding boys.

Of making the Moulds.—1. Each mould ought to present the exact form of its object.

2. It should have such solidity that the melted metal may be poured into it, and fill it entirely without altering its shape in any point.

3. The air which occupies the vacant spaces in it, as well as the carburetted gases generated by the heat, must have a ready vent; for if they are but partially confined, they expand by the heat, and may crack, even blow up the moulds, or at any rate become dispersed through the metal, making it vesicular and unsound.

There are three distinct methods of making the moulds:—

1. In green sand; 2. In baked sand; 3. In loam.

To enumerate the different means employed to make every sort of mould exceeds the limits prescribed to this work. We shall merely indicate for each species of moulding, what is common to all the operations; and then describe the fabrication of a few such moulds as appear most proper to give general views of this peculiar art

Moulding in green sand.—The name green is given to a mixture of the sand as it comes from its native bed, with about one twelfth its bulk of coal reduced to powder, and damped in such a manner as to form a porous compound, capable of preserving the forms of the objects impressed upon it. This sand ought to be slightly argillaceous, with particles not exceeding a pin's head in size. When this mixture has once served

for a mould, and been filled with metal, it cannot be employed again except for the coarsest castings, and is generally used for filling up the bottoms of fresh moulds.

For moulding any piece in green sand, an exact pattern of the object must be prepared in wood or metal; the latter being preferable, as not liable to warping, swelling, or shrinkage.

A couple of iron frames form a case or box, which serves as an envelope to the mould. Such boxes constitute an essential and very expensive part of the furniture of a foundry. It is a rectangular frame, without bottom or lid, whose two largest sides are united by a series of cross bars, parallel to each other, and placed from 6 to 8 inches apart.

The two halves of the box carry ears corresponding exactly with one another; of which one set is pierced with holes, but the other has points which enter truly into these holes, and may be made fast in them by cross pins or wedges, so that the pair becomes one solid body. Within this frame there is abundance of room for containing the pattern of the piece to be moulded with its encasing sand, which being rammed into the frame, is retained by friction against the lateral faces and cross bars of the mould.

When a mould is to be formed, a box of suitable dimensions is taken asunder, and each half, No. 1 and No. 2, is laid upon the floor of the foundry. Green sand is thrown with a shovel into No. 1 so as to fill it; when it is gently pressed in with a rammer. The object of this operation is to form a plane surface upon which to lay in the pattern with a slight degree of pressure, varying with its shape. No. 1 being covered with sand, the frame No. 2 is laid upon it, so as to form the box. No. 2 being now filled carefully with the green sand, the box is inverted, so as to place No. 1 uppermost, which is then detached and lifted off in a truly vertical position; carrying with it the body of sand formed at the commencement of the operation. The pattern remains imbedded in the sand of No. 2, which has been exactly moulded upon a great portion of its surface. The moulder condenses the sand in the parts nearest to the pattern, by sprinkling a little water upon it, and trimming the ill-shaped parts with small iron trowels of different kinds. He then dusts a little well-dried finely-sifted sand over all the visible surface of the pattern, and of the sand surrounding it; this is done to prevent adhesion when he replaces the frame No. 1.

He next destroys the preparatory smooth bed or area formed in this frame, covers the pattern with green sand, replaces the frame 1 upon 2 to reproduce the box, and proceeds to fill and ram No. 1, as he had previously done No. 2. The object of this operation is to obtain very exactly a concavity in the frame No. 1, having the shape of the part of the model impressed coarsely upon the surface formed at the beginning, and which was meant merely to support the pattern and the sand sprinkled over it, till it got imbedded in No. 2.

The two frames in their last position, along with their sand, may be compared to a box of which No. 1 is the lid, and whose interior is adjusted exactly upon the enclosed pattern.

If we open this box, and after taking out the pattern, close its two halves again, then pour in melted metal till it fill every void space, and become solid, we shall obviously attain the wished-for end, and produce a piece of cast iron similar to the pattern. But many precautions must still be taken before we can hit this point. We must first lead through the mass of sand in the frame No. 1, one or more channels for the introduction of the melted metal; and though one may suffice for this purpose, another must be made for letting the air escape. The metal is run in by several orifices at once, when the piece has considerable surface, but little thickness, so that it may reach the remotest points sufficiently hot and liquid.

The parts of the mould near the pattern must likewise be pierced with small holes, by means of wires traversing the whole body of the sand, in order to render the mould more porous, and to facilitate the escape of the air and the gases. Then, before lifting off the frame No. 1, we must tap the pattern slightly, otherwise the sand enclosing it would stick to it in several points, and the operation would not succeed. These gentle jolts are given by means of one or more pieces of iron wire which have been screwed vertically into the pattern before finally ramming the sand into the frame No. 1, or which enter merely into holes in the pattern. These pieces are sufficiently long to pass out through the sand when the box is filled; and it is upon their upper ends that the horizontal blows of the hammer are given; their force being regulated by the weight and magnitude of the pattern. These rods are then removed by drawing them straight out; after which the frame No. 1 may be lifted off smoothly from the pattern.

The pattern itself is taken out, by lifting it in all its parts at once, by means of screw pins adjusted at the moment. This manœuvre is executed, for large pieces, almost always by several men, who while they lift the pattern with one hand, strike it with the other with small repeated blows to detach the sand entirely, in which it is generally more engaged than it was in that of the frame No. 1. But in spite of all these precautions, there are always some degradations in one or other of the two parts

of the mould; which are immediately repaired by the workman with damp sand, which he applies and presses gently with his trowel, so as to restore the injured forms.

Hitherto it has been supposed that all the sand rammed into the box is of one kind; but from economy, the green sand is used only to form the portion of the mould next the pattern, in a stratum of about an inch thick; the rest of the surrounding space is filled with the sand of the floor which has been used in former castings. The interior layer round the pattern is called in this case, *new sand*.

It may happen that the pattern is too complex to be taken out without damaging the mould, by two frames alone; then three or more are mutually adjusted to form the box.

When the mould, taken asunder into two or more parts, has been properly repaired, its interior surface must be dusted over with wood charcoal reduced to a very fine powder, and tied up in a small linen bag, which is shaken by hand. The charcoal is thus sifted at the moment of application, and sticks to the whole surface which has been previously damped a little. It is afterwards polished with a fine trowel. Sometimes, in order to avoid using too much charcoal, the surfaces are finally dusted over with sand, very finely pulverised, from a bag like the charcoal. The two frames are now replaced with great exactness, made fast together by the ears, with wedged bolts laid truly level, or at the requisite slope, and loaded with considerable weights. When the casting is large, the charcoal dusting, as well as that of fine sand, is suppressed. Every thing is now ready for the introduction of the fused metal.

Moulding in baked or used sand. — The mechanical part of this process is the same as that of the preceding. But when the castings are large, and especially if they are tall, hydrostatic pressure of the melted metal upon the sides of the mould cannot be counteracted by the force of cohesion which the sand acquires by ramming. We must in that case adapt to each of these frames a solid side, pierced with numerous small holes to give issue to the gases. This does not form one body with the rest of the frame, but is attached extemporaneously to it by bars and wedged bolts. In general no ground coal is mixed with this sand. Whenever the mould is finished, it is transferred to the drying stove, where it may remain from twelve to twenty-four hours at most, till it be deprived of all its humidity. The sand is then said to be baked, or annealed. The experienced moulder knows how to mix the different sands placed at his disposal, so that the mass of the mould as it comes out of the stove, may preserve its form, and be sufficiently porous. Such moulds allow the gases to pass through them much more readily than those made of *green* sand; and in general the castings they turn out are less vesicular, and smoother upon the surface. Sometimes in a large piece, the three kinds of moulding, that in green sand, in baked sand, and in loam, are combined to produce the best result.

Moulding in loam. — This kind of work is executed from drawings of the pieces to be moulded, without being at the expense of making patterns. The mould is formed of a pasty mixture of clay, water, sand, and cow's hair, or other cheap filamentous matter, kneaded together in what is called the loam mill. The proportions of the ingredients are varied to suit the nature of the casting. When the paste requires to be made very light, horse dung or chopped straw is added to it.

We shall illustrate the mode of fabricating loam moulds, by a simple case, such as that of a sugar pan. *Fig.* 870 is the pan. There is laid upon the floor of the foundry, an

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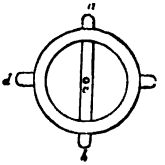

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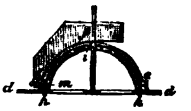

annular platform of cast-iron, *a*, *b*, *fig.* 871; and upon its centre *c*, rests the lower extremity of a vertical shaft, adjusted so as to turn freely upon itself, while it makes a wooden pattern *e f*, *fig.* 872, describe a surface of revolution identical with the internal surface reversed of the boiler intended to be made. The outline *e g*, of the pattern is fashioned so as to describe the surface of the edge of the vessel. Upon the part *a*, *d*, *b*, *d*, *fig.* 872, of the flat cast-iron ring, there must next be constructed, with bricks laid either flat or on their edge, and clay, a kind of dome, *h i k*, *fig.* 872, from two to four inches thick, according to the size and weight of the piece to be moulded. The external surface of the brick dome ought to be everywhere two inches distant at least, from the surface described by the arc *e*, *f*. Before building up the dome to the point *i*, coals are to be placed in its inside upon the floor, which may be afterwards kindled for drying the mould. The top is then formed, leaving at *i*, round the upright shaft

of revolution, only a very small outlet. This aperture, as also some others left under the edges of the iron ring, enable the moulder to light the fire when it becomes necessary, and to graduate it so as to make it last long enough without needing more fuel, till the mould be quite finished and dry. The combustion should be always extremely slow.

Over the brick dome a pasty layer of loam is applied, and rounded with the mould *g, e, f*; this surface is then coated with a much smoother loam, by means of the concave edge of the same mould. Upon the latter surface, the inside of the sugar pan is cast; the line *e g* having traced, in its revolution, a ledge, *m*. The fire is now kindled, and as the surface of the mould becomes dry, it is painted over by a brush with a mixture of water, charcoal powder, and a little clay, in order to prevent adhesion between the surface already dried and the coats of clay about to be applied to it. The board *g e f* is now removed, and replaced by another, *g' e' f'*, *fig.* 874, whose edge *e' f'* describes the outer surface of the pan. Over the surface *e, f*, a layer of loam is applied, which is turned and polished so as to produce the surface of revolution *e' f'*, as was done for the surface *e f*; only in the latter case, the line *e' g'* of the board does not form a new shoulder, but rubs lightly against *m*.

The layer of loam included between the two surfaces *e f*, *e' f'*, is an exact representation of the sugar pan. When this layer is well dried by the heat of the interior fire, it must be painted like the former. The upright shaft is now removed, leaving the small vent hole through which it passed to promote the complete combustion of the coal There must be now laid horizontally upon the ears of the platform *d d*, *fig.* 871, ano-

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ther annular platform *p q*, like the former, but a little larger, and without any cross-bar. The relative position of these two platforms is shown in *fig.* 875. Upon the surface *e' f'*, *fig.* 874, a new layer of loam is laid, two inches thick, of which the surface is smoothed by hand. Then upon the platform *p q*, *fig.* 875, a brick vault is constructed, whose inner surface is applied to the layer of loam. This contracts a strong adherence with the bricks which absorb a part of its moisture, while the coat of paint spread over the surface *e' f'*, prevents it from sticking to the preceding layers of loam. The brick dome ought to be built solidly.

The whole mass is now to be thoroughly dried by the continuance of the fire, the draught of which is supported by a small vent left in the upper part of the new dome; and when all is properly dry, the two iron platforms are adjusted to each other by pin points, and *p q* is lifted off, taking care to keep it in a horizontal position. Upon this platform are removed the last brick dome, and the layer of loam which had been applied next to it; the latter of which represents exactly by its inside the mould of the surface *e' f'*, that is, of the outside of the pan. The crust contained between *e f* and *e' f'* is broken away, an operation easily done without injury to the surface *e f*, which represents exactly the inner surface of the pan; or only to the shoulder *m*, corresponding to the edge of the vessel. The top aperture through which the upright shaft passed must be now closed; only the one is kept open in the portion of the mould lifted off upon *p q*; because through this opening the melted metal is to be poured in the process of casting. The two platforms being replaced above each other very exactly, by means of the adjusting pin-points, the mould is completely formed, and ready for the reception of the metal.

When the object to be moulded presents more complicated forms than the one now chosen for the sake of illustration, it is always by analogous processes that the workman constructs his loam moulds, but his sagacity must hit upon modes of executing many things which at first sight appear to be scarcely possible. Thus, when the forms of the interior and exterior do not permit the mould to be separated in two pieces, it is divided into several, which are nicely fitted with adjusting pins. More than two cast-iron rings or platforms are sometimes necessary. When ovals or angular surfaces must be traced instead of those of revolution, no upright shaft is used, but wooden or cast-iron guides made on purpose, along which the pattern cut-out board is slid according to the drawing of the piece. Iron wires and claws are often interspersed through the brick

work to give it cohesion. The core, kernel, or inner mould of a hollow casting is frequently fitted in when the outer shell is moulded. The case of a gas-light retort, *fig.* 876, will illustrate this matter. The core of the retort ought to have the form *e e e*, and be very solid, since it cannot be fixed in the outer mould for the casting, except in the part standing out of the retort towards *m m*. It must be modelled in loam, upon a piece of cast-iron called a *lantern*, made expressly for this purpose. The lantern is a cylinder or a truncated hollow cone of cast iron, about half an inch thick; and differently shaped for every different core. The surface is perforated with holes of about half an inch in diameter. It is mounted by means of iron crossbars, upon an iron axis,

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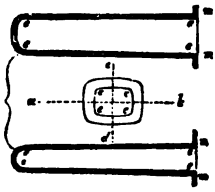

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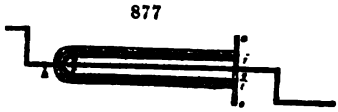

which traverses it in the direction of its length. *Fig.* 877 represents a horizontal section through the axis of the core; *g h* is the axis of the lantern, figured itself at *i k k i*; *o i i o* is a kind of disc or dish, perpendicular to the axis, open at *i i*, forming one piece with the lantern, whose circumference *o o* presents a curve similar to the section of the core, made at right angles to its axis. We shall see presently the two uses for which this dish is intended. The axis *g h* is laid upon two gudgeons, and handles are placed at each of its extremities, to facilitate the operation in making the core. Upon the whole surface of the lantern, from the point *h* to the collet formed by the dish, a hay cord as thick as the finger is wound. Even two or more coils may be applied, as occasion requires, over which loam is spread to the exact form of the core, by applying with the hand a board, against the dish *o o*, with its edge cut out to the desired shape; as also against another dish, adjusted at the time towards *h*; while by means of the handles a rotatory movement is given to the whole apparatus.

The hay interposed between the lantern and the loam, which represents the crust of the core, aids the adhesion of the clay with the cast iron of the lantern, and gives passage to the holes in its surface, for the air to escape through in the casting.

When the core is finished, and has been put into the drying stove, the axis *g h* is taken out, then the small opening which it leaves at the point *h*, is plugged with clay. This is done by supporting the core by the edges of the dish, in a vertical position. It is now ready to be introduced into the hollow mould of the piece.

This mould executed in baked sand consists of three pieces, two of which, absolutely similar, are represented, *fig.* 878, at *p q*, the third is shown at *r s*. The two similar parts *p q*, present each the longitudinal half of the nearly cylindrical portion of the outer surface of the gas retort; so that when they are brought together, the cylinder is formed; *r s* contains in its cavity the kind of hemisphere which forms the bottom of the retort. Hence, by adding this part of the mould to the end of the two others, the resulting apparatus presents, in its interior, the exact mould of the outside of the retort; an empty cylindrical portion *t t*, whose axis is the same as that of the cylinder *u u*, and whose surface, if prolonged, would be every where distant from the surface *u u*, by a quantity equal to the desired thickness of the retort. The diameter of the cylinder *t t* is precisely equal to that of the core, which is slightly conical, in order that it may enter easily into this aperture *t t*, and close it very exactly when it is introduced to the collet or neck.

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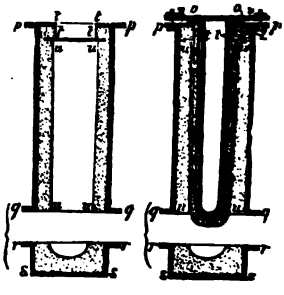


The three parts of the mould and the core being prepared, the two pieces *p q*, must first be united, and supported in an upright position; then the core must be let down into the opening *t t*, *fig.* 879. When the plate or disc *o o* of the core is supported upon the mould, we must see that the end of the core is everywhere equally distant from the edge of the external surface *u u*, and that it does not go too far beyond the line *q q*. Should there be an inaccuracy, we must correct it by slender iron slips placed under

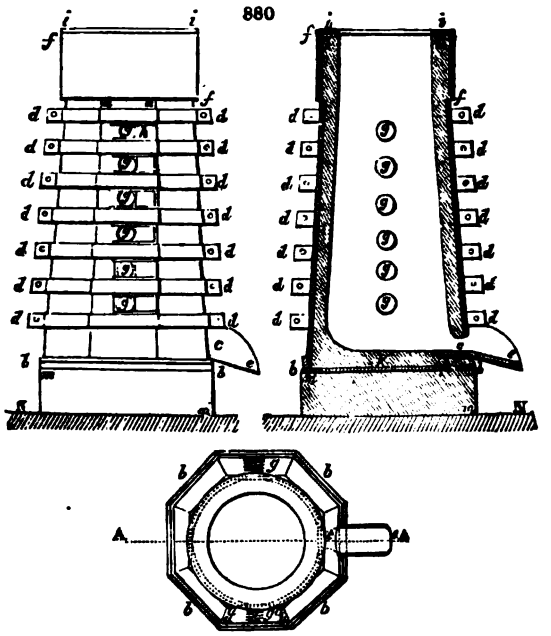
the edge of the disc *o o*; then by means of a cast iron cross, and screw bolts *v v*, we fix the core immovably. The whole apparatus is now set down upon *r s*, and we fix with screw bolts the plane surface *q q* upon *r r*; then introduce the melted metal by an aperture *z*, which has been left at the upper part of the mould.

When, instead of the example now selected, the core of the piece to be cast must go beyond the mould of the external surface, as is the case with a pipe open at each end, the thing is more simple, because we may easily adjust and fix the core by its two ends.

In casting a retort, the metal is poured into the mould set upright. It is important to maintain this position in the two last examples of casting; for all the foreign matters which may soil the metal during its flow, as the sand, the charcoal, gases, scoriæ, being less dense than it, rise constantly to the surface. The hydrostatic pressure produced by a high gate, or filling-in aperture, contributes much to secure the soundness and solidity of the casting. This gate piece being superfluous, is knocked off almost immediately after, or even before the casting cools. Very long, and somewhat slender pieces, are usually cast in moulds set up obliquely to the horizon. As the metal shrinks in cooling, the mould should always be somewhat larger than the object intended to be cast. The iron founder reckons in general upon a linear shrinkage of a ninety-sixth part; that is one-eighth of an inch per foot.

Melting of the cast-iron.—The metal is usually melted in a cupola furnace, of which the dimensions are very various. *Fig.* 880 represents in plan, section, and elevation,

880



one of these furnaces of the largest size; being capable of founding 5 tons of cast-iron at a time. It is kindled by laying a few chips of wood upon its bottom, leaving the orifice *c* open, and it is then filled up to the throat with coke. The fire is lit at *c*, and in a quarter or half an hour, when the body of fuel is sufficiently kindled, the tuyère blast is set in action. The flame issues then by the mouth as well as the orifice *c*, which has been left open on purpose to consolidate it by the heat. Without this precaution, the sides, which are made up in argillaceous sand after each day's work, would not present the necessary resistance. A quarter of an hour afterwards, the orifice *c* is closed with a lump of moist clay, and sometimes, when the furnace is to contain a great body of melted metal, the clay is supported by means of a small plate of cast-iron fixed against the furnace. Before the blowing machine is set agoing, the openings *g g g* had been kept shut. Those of them wanted for the tuyères are opened in

succession, beginning at the lowest, the tuyères being raised according as the level of the fused iron stands higher in the furnace. The same cupola may receive at a time from one to six tuyères, through which the wind is propelled by the centrifugal action of an excentric fan or ventilator. It does not appear to be ascertained whether there be any advantage in placing more than two tuyères facing each other upon opposite sides of the furnace. Their diameter at the nozzle varies from 3 to 5 inches. They are either cylindrical or slightly conical. A few minutes after the tuyères have begun to blow, when the coke sinks in the furnace, alternate charges of coke and pig iron must be thrown in. The metal begins to melt in about 20 minutes after its introduction; and successive charges are then made every 10 minutes nearly; each charge containing from 3 cwt. to 5 cwt. of iron, and a quantity proportional to the estimate given below. The amount of the charges varies of course with the size of the furnace, and the speed required for the operation. The pigs must be previously broken into pieces weighing at most 14 or 16 pounds. The vanes of the blowing fan make from 625 to 650 turns per minute. The two cupolas represented *fig.* 881, and another alongside in the plan, may easily melt 6½ tons of metal in 2¾ hours; that is 2¼ tons per hour. This result is three or four times greater than what was formerly obtained in similar cupolas, when the blast was thrown in from small nozzles with cylinder bellows, moved by a steam engine of 10 horses power.

In the course of a year, a considerable foundry like that represented in the plan, *fig.* 869, will consume about 300 tons of coke in melting 1240 tons of cast iron; consisting of 940 tons of pigs, of different qualities, and 300 tons of broken castings, gate-pieces, &c. Thus it appears that 48 pounds of coke are consumed for melting every 2 cwt. of metal.

Somewhat less coke is consumed when the fusion is pushed more rapidly, to collect a great body of melted metal for casting heavy articles; and more is consumed when, as in making many small castings, the progress of the founding has to be slackened from time to time; otherwise, the metal would remain too long in a state of fusion, and probably become too cold to afford sharp impressions of the moulds.

It sometimes happens that in the same day, with the same furnace, pieces are to be cast containing several proportions of different kinds of iron; in which case, to prevent an intermixture with the preceding or following charges, a considerable bed of coke is interposed. Though there be thus a little waste of fuel, it is compensated by the improved adaptation of the castings to their specific objects. The founding generally begins at about 3 o'clock, P.M., and goes on till 6 or 8 o'clock. One founder aided by four labourers for charging, &c., can manage two furnaces.

The following is the work of a well-managed foundry in Derby.

200 lbs. of coke are requisite to melt, or bring down (in the language of the founder), 1 ton of cast iron, after the cupola has been brought to its proper heat, by the combustion in it of 9 baskets of coke, weighing, by my trials, 40 pounds each, = 360 lbs.

The chief talent of the founder consists in discovering the most economical mixtures and so compounding them as to produce the desired properties in the castings. One piece, for example, may be required to have great strength and tenacity to bear heavy weights or strains; another must yield readily to the chisel or the file; a third must resist sudden alternations of temperature; and a fourth must be pretty hard.

The filling in of the melted metal is managed in two ways. For strong pieces, whose moulds can be buried in the ground at 7 or 8 yards distance from the furnace, the metal may be run in gutters, formed in the sand of the floor, sustained by plates or stones. The clay plug is pierced with an iron rod, when all is ready.

When from the smaller size, or greater distance of the moulds, the melted metal cannot be run along the floor from the furnace, it is received in cast-iron pots or ladles, lined with a coat of loam. These are either carried by the hands of two or more men, or transported by the crane. Between the successive castings, the discharge hole of the furnace is closed with a lump of clay, applied by means of a stick, having a small disc of iron fixed at its end.

After the metal is somewhat cooled, the moulds are taken asunder, and the excrescences upon the edges of the castings are broken off with a hammer. They are afterwards more carefully trimmed or chipped by a chisel when quite cold. The loss of weight in founding is about 6½ per cent. upon the pig iron employed. Each casting always requires the melting of considerably more than its own weight of iron. This excess forms the gates, false seams, &c.; the whole of which being deducted, shows that 1 cwt. of coke is consumed for every 3 cwt. of iron put into the furnace; for every 138 cwt. of crude metal, there will be 100 cwt. of castings, 32 of refuse pieces, and 6 of waste.

Fig. 880, *Cupola furnace,* requires a little further description. It is 3 feet wide within, and 13½ feet high. *m m*, solid body of masonry, as a basis to the furnace.

b b, octagonal platform of cast iron, with a ledge in which the plates *a a a a* are engaged.

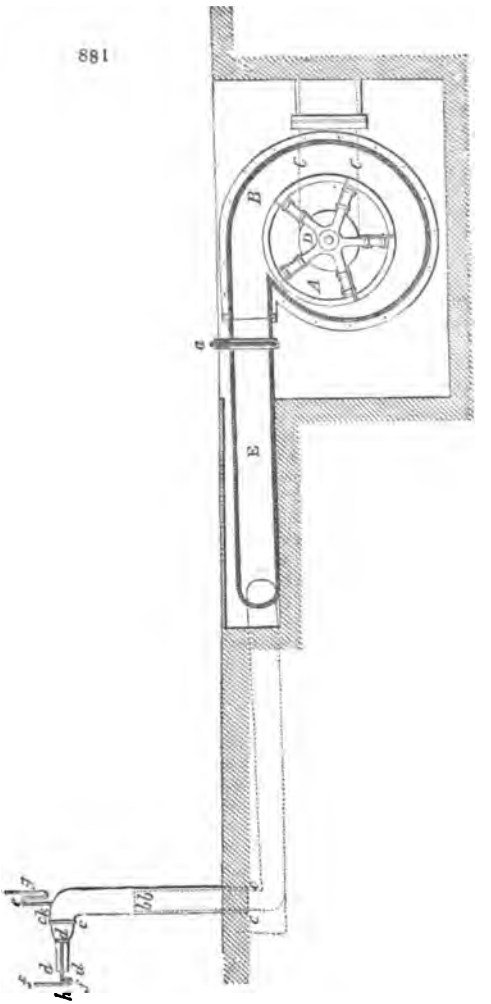
a a, eight plates of cast iron, 1 inch thick, absolutely similar; only one of them is notched at its lower part in *c*, to allow the melted metal to run out, and two of the others have six apertures, *g g g*, &c. to admit the tuyères.

c, orifice for letting the metal flow out. A kind of cast iron gutter, *e*, lined with loam, is fitted to the orifice.

d, hoops of hammered iron, 4½ inches broad; one half of an inch thick for the bottom ones; and a quarter of an inch for the upper ones. The intermediate hoops decrease in thickness from below upwards between these limits.

e, cast iron gutter or spout, lined with loam, for running off the metal.

f f, cylindrical piece of cast iron, for increasing the height and draught of the furnace.



g, side openings for receiving the tuyères, of which there are six upon each side of the furnace. Each of them may be shut at pleasure, by means of a small cast iron plate, *h*, made to slide horizontally in grooves sunk in the main plate, pierced with the holes *g g*.

k k, interior lining of the surface, made of sand, somewhat argillaceous, in the following way. After having laid at the bottom of the furnace a bed of sand a few inches thick, slightly sloped towards the orifice of discharge, there is set upright, in the axis of the cupola, a wooden cylinder of its whole height, and of a diameter a little less than that of the vacant space belonging to the top of the furnace. Sand is to be then rammed in so as to fill the whole of the furnace; after which the wooden cylinder is withdrawn, and the lining of the sand is cut or shaved away, till it has received the proper form.

This lining lasts generally 5 or 6 weeks, when there are six meltings weekly.

i i, cast iron circular plate, through which the mouth of the furnace passes for protecting the lining in *k* during the introduction of the charges.

N N, level of the floor of the foundry. The portion of it below the running out orifice consists of sand, so that it may be readily sunk when it is wished to receive the melted metal in ladles or pots of large dimensions.

The fan distributes the blast from the main pipe to three principal points, by three branch tubes of distribution. A register, consisting of a cast iron plate sliding with friction in a frame, serves to intercept the blast at any moment, when it is not desirable to stop the moving power. A large main pipe of zinc or sheet iron is fitted to the orifice of the slide valve. It is square at the beginning, or only rounded at the angles; but at a little distance it becomes cylindrical, and conducts the blast to the

divaricating points. There, each of the branches turns up vertically, and terminates at *b b*, *fig.* 881, where it presents a circular orifice of 7½ inches. Upon each of the upright pipes *b*, the one end of an elbow-tube of zinc *c c c c*, *fig.* 881, is adjusted rather loosely, and the other end receives a tuyère of wrought iron *d d*, through the intervention of a shifting hose or collar of leather *c c d*, hooped with iron wire to both the tube and the tuyère. The portion *c c c c* may be raised or lowered, by sliding upon the pipe *b*, in order to bring the nozzle of the tuyère *d d*, to the requisite point of the furnace. The portion *c c c c* may be made also of wrought iron. A power of 4 horses is adequate to drive this fan, for supplying blast to 3 furnaces.

The founders have observed that the efflux of air was not the same when blown into the atmosphere, as it was when blown into the furnaces; the velocity of the fan, with the same impulsive power, being considerably increased in the latter case. They imagine that this circumstance arises from the blast being sucked in, so to speak, by the draught of the furnace, and that the fan then supplied a greater quantity of air.

The following experimental researches show the fallacy of this opinion. Two water siphons, *e e e*, *f f f*, made of glass tubes, one-fifth of an inch in the bore, were inserted into the tuyère, containing water in the portions *g g g*, *h h h*. The one of these *manometers* for measuring the pressure of the air was inserted at *k*, the other in the centre of the nozzle. The size of this glass tube was too small to obstruct in any sensible degree the outlet of the air. It was found that when the tuyères of the fan discharged into the open air, the expenditure by a nozzle of a constant diameter was proportional to the number of the revolutions of the vanes. It was further found, that when the speed of the vanes was constant, the expenditure by one or two nozzles was proportional to the total area of these nozzles. The following formulæ give the volume of air furnished by the fan, when the number of turns and the area of the nozzles are known.

$$\text{Volume} = \frac{25{\cdot}32\ S\ n}{1{\cdot}000{,}000} \quad (1)$$

$$\text{Volume} = \frac{0{\cdot}86'6'7\ S\ n}{1{,}000{,}000} \quad (2)$$

The volume is measured at 32° Fahr., under a pressure of 29·6 inches barom.

S = is the total area of the orifices of the tuyères in square inches.

n = the number of turns of the vanes in a minute.

After measuring the speed of the vanes blowing into the atmosphere, if we introduce the nozzle of discharge into the orifice of the furnace, we shall find that their speed immediately augments in a notable degree. We might, therefore, naturally suppose that the fan furnishes more air in the second case than in the first; but a little reflection will show that it is not so. In fact, the air which issues in a cold state from the tuyère encounters instantly in the furnace a very high temperature, which expands it, and contributes, along with the solid matters with which the furnace is filled, to diminish the facility of the discharge, and consequently to retard the efflux by the nozzles. The oxygen gas consumed is replaced by a like volume of carbonic acid gas, equally expansible by heat. Reason leads us to conclude that less air flows from the nozzles into the furnace than into the open atmosphere.

The increase in the velocity of the vanes takes place precisely in the same manner, when after having made the nozzles blow into the atmosphere, we substitute for these nozzles others of a smaller diameter, instead of directing the larger ones into the furnace. Hence we may conceive that the proximity of the charged furnace acts upon the blast like the contraction of the nozzles. When the moving power is uniform, and the velocity of the vanes remains the same, the quantity of air discharged must also be the same in the two cases.

Two tuyères, one 5 inches in diameter, the other 4½, and which, consequently, presented a total area of 35½ square inches, discharged air into one of the furnaces, from a fan whose vanes performed 654 turns in the minute. These two nozzles being briskly withdrawn from the furnace, and turned round to the free air, while a truncated pasteboard cone of 3½ inches diameter was substituted for the nozzle of 4½ inches, whereby the area of efflux was reduced to 29·3 square inches, the velocity of the vanes continued exactly the same. The inverse operation having been performed, that is to say, the two original nozzles having been smartly replaced in the furnace, to discover whether or not the moving power had changed in the interval of the experiment, they betrayed no perceptible alteration of speed. From the measures taken to count the speed, the error could not exceed 3 revolutions per minute, which is altogether unimportant upon the number 654.

It follows, therefore, that when the vanes of the fan have the velocity of 654 turns per minute, the expenditure by two nozzles, whose joint area is 35½ square inches, both blowing into a furnace, is to the expenditure which takes place, when the same nozzles blow into the air, as 35·5 is to 29·3; that is, a little more than 4-fifths.

If this be, as is probable, a general rule for areas and speeds considerably different from the above, to find the quantity of air blown into one or more furnaces by the fan, we should calculate the volume by one of the above formulæ (1) or (2), and take 4-fifths of the result, as the true quantity.

The fan A C, represented (*fig.* 881), is of the best excentric form, as constructed by Messrs. Braithwaite and Ericsson. D is the circular orifice round the axis by which the air is admitted; and C C B is the excentric channel through which the air is wafted towards the main discharge pipe B. See VENTILATION.

FOUNTAIN. A stream of water rising up through the superficial strata of the earth. See ARTESIAN WELLS.

FOXING, is a term employed by brewers to characterise the souring of beer, in the process of its fermentation or ripening.

FRACTIONAL DISTILLATION. See NAPHTHA (BOGHEAD).

FRACTURE of minerals. The fracture of minerals has been grouped under the following heads, there being very few variations from them:—

1. *Conchoidal*; from concha, like *a shell*, when a mineral breaks with curved concavities; example, flint.

2. *Even*; when the surface of fracture is rough, with numerous small elevations and depressions.

3. *Splintery*; when the broken surface exhibits protruding points.

4. *Hackly*; when the elevations are sharp or jagged, as iron.

FRAME, *a mining term.* See ORE DRESSING.

FRANKFORT BLACK; is a black used in copper-plate printing. It is said to be a charcoal obtained from grape and vine lees, peach kernels, and bone shavings. It is, doubtful, whether the finest black is not a soot produced from the combustion of some of these bodies. The preparation is, however, made much of a mystery.

FRANKINCENSE. The spontaneous exudations of the *Abies excelsa*, the *Norway spruce fir.*

FRANKLINITE. A somewhat remarkable mineral, which is found at Hamburg, N. J., with red oxide of zinc and garnet in granular limestone. Its composition has been determined to be—

	1.	2.	3.
Oxide of iron -	66·0	68·88	66·12
Oxide of manganese -	18·0	18·17	11·19
Oxide of zinc -	17·0	10·81	21·77

Franklinite was at first employed for the production of zinc; but for that purpose it did not answer commercially. It is, however, now employed in combination with iron, as it is said, with much advantage. Major Farrington of New Jersey thus speaks of it:—"Many experiments have been made under my superintendence upon the ores of Franklinite, and I have also witnessed several others of an interesting character made by other parties in mixing Franklinite with pig iron in the puddling furnace, and also a mixture of franklinite pig with other irons in their conversion to wrought iron. The result in all cases has been a great improvement in the quality of iron as manufactured. The most marked and, as I consider, the most valuable result is obtained by using from 10 to 15 per cent. of the weight of pig iron to be puddled with pulverised Franklinite ore in the furnace at each heat. Iron of the most inferior quality when thus treated, is converted into an article of No. 1 grade. The volatile nature of zinc at a high temperature, combining with the sulphur, phosphorus, and other volatile constituents of the coal, or that may be in the iron, being carried off mechanically, I consider is one of the causes of the improvement; the manganese also of the ore combines with silica at a high temperature, and pig iron that contains silica is thus freed from it. The great advantage to be obtained by using the pulverised ore in the puddling furnace is, that a high grade of iron may be made; and where reheating has been hitherto deemed indispensable, one heating is found sufficient for such uses as wire billets, nuts, bolts, horseshoe iron, and nails. A particular selection of fuel is not required, coke and charcoal can be dispensed with, and bituminous or anthracite coal used."

FREESTONE. A term used to denote any stone which is capable of being worked freely in every direction, and, which has no tendency to break in one direction more than another. In the counties of Wicklow and Dublin, and also in Cornwall, the term is applied to granite which works freely.—H. W. B.

FREEZING. (*Congelation*, Fr.; *Gefrierung*, Germ.) The three general forms, solid, liquid, and gaseous, under one or other of which all kinds of matter exist, are

referrible to the influence of heat, modifying, balancing, or subduing the attraction of cohesion. Nearly every solid may be liquefied, and every liquid may be vaporised, by a certain infusion of heat, whether this be regarded as a moving power, or an elastic essence. The converse of this proposition is equally true; for many gases, till lately styled permanent, may be liquefied, nay, even solidified, by diminution of their temperature, either alone, or aided by a sufficient mechanical condensation, to bring their particles within the sphere of aggregative attraction. When a solid is transformed into a liquid, and a liquid into a gas or vapour, a quantity more or less considerable of heat is absorbed, or becomes latent, to use the term of Dr. Black. When the opposite transformation takes place, the heat absorbed is again emitted, or what was latent becomes sensible. See HEAT for the more recent hypotheses.

The production of cold is a curious and interesting branch of physical inquiry. A few general laws may be distinctly named.

If a solid body suddenly liquefies, without the application of external heat, it abstracts from the surrounding bodies the heat necessary for its liquefaction.

When a salt is dissolved in water cold is produced.

If a liquid vaporises, the vapour is produced at the expense of the heat of some neighbouring body.

When spirits of wine, or ether, is thrown on the body, a sensation of coldness is produced from the liquids vaporising by robbing the body of heat.

By placing water in a porous vessel, and exposing it to the sun, it becomes very cold. The solar heat-rays occasion a rapid evaporation of the water which has filtered through the pores of the vessel, and some heat is taken by the process from the fluid in the interior.

If air is allowed suddenly to expand, it takes heat from the surrounding bodies, or produces cold.

The most familiar method of producing intense cold is by means of freezing mixtures. A great number of those were invented by Mr. Walker; the principal results are contained in the following tables: —

I. — Table, consisting of Frigorific Mixtures, having the power of generating or creating cold without the aid of ice, sufficient for all useful and philosophical purposes, in any part of the world at any season.

Frigorific Mixtures without Ice.

MIXTURES.	Thermometer sinks.	Deg. of cold produced.
Nitrate of ammonia - - 1 part Water - - - - 1	From + 50° to + 4°	46°
Muriate of ammonia - - 5 parts Nitrate of potash - - 5 Water - - - - 16	From + 50° to + 10°	40
Muriate of ammonia - - 5 parts Nitrate of potash - - 5 Sulphate of soda - - 8 Water - - - - 16	From + 50° to + 4°	46
Sulphate of soda - - 3 parts Diluted nitric acid - - 2	From + 50° to − 3°	53
Nitrate of ammonia - - 1 part Carbonate of soda - - 1 Water - - - - 1	From + 50° to − 7°	57
Phosphate of soda - - 9 parts Dilute nitric acid - 4	From + 50° to − 12°	62
Sulphate of soda - - 8 parts Hydrochloric acid - - 5	From + 50° to 0°	50
Sulphate of soda - - 5 parts Dilute sulphuric acid - 4	From + 50° to + 3°	47
Sulphate of soda - - 6 parts Muriate of ammonia - - 4 Nitrate of potash - - 2 Dilute nitric acid - - 4	From + 50° to −10°	60
Sulphate of soda - - 6 parts Nitrate of ammonia - - 5 Dilute nitric acid - - 4	From + 50° to − 14°	64

II. — Table consisting of Frigorific Mixtures, composed of ice, with chemical salts and acids.

Frigorific Mixtures with Ice.

MIXTURES.		Thermometer sinks.	Deg. of cold produced.
Snow, or pounded ice - 2 parts Muriate of soda - - 1	From any temperature	to − 5°	*
Snow, or pounded ice - 5 parts Muriate of soda - - - 2 Muriate of ammonia - - 1		to − 12°	*
Snow, or pounded ice - 24 parts Muriate of soda - - 10 Muriate of ammonia - - 5 Nitrate of potash - - 5		to − 18°	*
Snow, or pounded ice - 12 parts Muriate of soda - - 5 Nitrate of ammonia - - 5		to − 25°	*
Snow - - - - 3 parts Dilute sulphuric acid - 2		From + 32° to − 23°	55
Snow - - - - 8 parts Muriatic acid - - - 5		From + 32° to − 27°	59
Snow - - - - 7 parts Dilute nitric acid - - 4		From + 32° to − 30°	62
Snow - - - - 4 parts Muriate of lime - - 5		From + 32° to − 40°	72
Snow - - - - 2 parts Cryst. muriate of lime - 3		From + 32° to − 50°	82
Snow - - - - 3 parts Potash - - - - 4		From + 32° to − 51°	83

N. B. — The reason for the omissions in the last column of the preceding table is, the thermometer sinking in these mixtures to the degree mentioned in the preceding column, and never lower, whatever may be the temperature of the materials at mixing.

To produce these results in a satisfactory manner, it is necessary to cool previously to the experiments, the vessels in which the mixtures are made.

The most intense cold that is as yet known is that from the evaporation of a mixture of solid carbonic acid and sulphuric ether, by which a temperature of 166° Fahr. below the freezing point of water is produced. By means of this intense cold, assisted by mechanical pressure several of the gaseous bodies have been condensed into liquids, and in some instances solidified.

Sir John Herschel, some years since, recommended the following method for obtaining at moderate cost large quantities of ice.

A steam engine boiler was to be sunk into the earth, and the quantity of water which it was desired to freeze placed in it. By means of a condensing pump, several atmospheres of air were forced into the boiler, and then everything was allowed to remain for a night, or until the whole had acquired the temperature of the surrounding earth. Then, by opening a stop cock, the air expanding escaped with much violence, and the water being robbed of its heat to supply the expanding air, the temperature of the whole was so reduced, that a mass of ice was the result.

The following process for producing cold has been patented and exhibited in this country.

In a reservoir, or what may with propriety be called a boiler, was placed a quantity of sulphuric ether. This reservoir was placed in a long vessel of saline water, this fluid by the arrangement being made to flow from one end of the trough to the other, that is to and from the reservoir. In this water was placed a number of vessels, the depth and breadth of the trough, but of only two inches in width, and these were filled with the water to be frozen.

A steam engine was employed to pump the air from the reservoir ; this being done, of course the ether boiled, and the vapour of the ether was removed by the engine as fast as it was formed. The heat required to vaporise the ether was derived from the saline water in the trough, and this again took the heat from the water in the cells; thus eventually every cell of water was converted into ice. The ether was, after it had passed through the engine, condensed by a refrigeratory of the ordinary kind.

The statement made by the patentee was very satisfactory, as it regarded the cost of production. An apparatus of this kind is of course intended for hot countries only, where ice becomes actually one of the necessaries of life.

A peculiar physical fact connected with the freezing of water has been made available to some important uses. Water in freezing really rejects everything it may contain — even air, and hence solid ice is actually *pure* water. This may be easily proved. Make a good freezing mixture, and place some water in a flask, and while it is undergoing consolidation by being placed in the frigorific compound, gently agitate it with a feather. Now, if the water contains spirit, acid, salt, or colouring matter, either of them are alike rejected, and the solid obtained, when washed from the matter adhering to its surface is absolutely pure solid water.

This philosophic fact, although it has only been subjected to examination within the last few years, has been long known.

Byron, in his 13th Canto of Don Juan, has the following allusion to it: —

> "I'll have another figure in a trice:
> What say you to a bottle of champagne?
> Frozen into a very vinous ice,
> Which leaves few drops of that immortal rain,
> Yet in the very centre, past all price,
> About a liquid glassful will remain;
> And this is stronger than the strongest grape
> Could e'er express in its expanded shape."

The old nobles of Russia, when they desired a more intoxicating drink than usual, placed their wines or spirit in the ice of their frozen rivers, until all the aqueous portion was frozen; when they drank the ardent fluid accumulated in the centre. This plan has been employed also for concentrating lemon juice and the like. For some further matters connected with this peculiar condition, see STEAM BOILERS and WATER.

FRENCH BERRIES. The berries of the *Rhamnus catharticus*, and other species of the Buckthorn. The true French berries, which should be four-seeded, belong to the first named; all the two-seeded berries are obtained from other and inferior kinds.

FRENCH CHALK. A steatite; a soft magnesian mineral.

FRENCH POLISH. There are numerous methods given for the preparation of this polish, one of the best is probably the following: 1½ lbs. of shell lac dissolved in a gallon of spirits of wine without heat. Another recipe is 12 ounces of shell lac, 2 ounces of gum elemi, and 3 ounces of copal to 1 gallon of spirits of wine.

FRICTION. The resistance to motion which depends on the structure of the surfaces in contact. Friction is usually divided into two kinds: *sliding friction* and *rolling friction*. The questions involved in the consideration of friction are purely engineering, and cannot therefore be treated here. One very important element may however be named, as showing the importance of exact science in connection with the improvements in mechanics. By friction *heat* is evolved. It is found by accurate experiment, that the *quantity of heat evolved is exactly sufficient to reproduce the effort caused in overcoming the friction. — Joule and Thomson.*

FRIT. See ENAMEL and GLASS.

FUCUS. See ALGÆ. In the *Fucus serratus* and *ceramoides* silver has been detected, *Malaguto* has stated, to the extent of $\frac{1}{10000}$, in the ashes of these plants. It has also been stated that these and some other plants contain lead and copper.

FUD, or WOOLLEN WASTE, is the refuse of the new wool taken out in the scribbling process, and is mixed with the mungo for use. See MUNGO.

FUEL. (*Combustible*, Fr; *Brennstoff*, Germ.)

Such combustibles as are used for fires or furnaces. Wood, Turf, Coal, are familiar examples. Fuels differ in their nature, and in their power of giving heat, it is therefore of much importance to ascertain the heat-giving power. Numerous excellent experiments have been made for the purpose of determining with exactness the heating values of fuels of different kinds. Lavoisier and Laplace, in an extensive examination carried out by them, used the well known *Calorimeter*, that is, they determined the value of the heat by the quantity of ice melted in a given time. Count Rumford subsequently measured the quantity of heat by the increase of temperature in a given quantity of water. The quantity of heat which will melt 1 lb. of ice at 0° Cent. being just sufficient according to Laplace to raise the temperature of a pound of water to 75° Cent., or according to the experiments of Regnault, to 79° Cent. Clement and Desormes have also shown, that an equal weight of aqueous vapour, whatever may be its temperature and tension, is always produced by one and the same amount of heat.

As far as we can within the limits of the present work, we shall endeavour to present a full practical view of the subject, giving each class of fuels under their several heads.

I. *Wood*, which is divided into hard and soft. To the former belong the oak,

the beech, the alder, the birch, and the elm; to the latter, the fir, the pine of different sorts, the larch, the linden, the willow, and the poplar.

Under like dryness and weight, different woods are found to afford very different degrees of heat and combustion. Moisture diminishes the heating power in three ways: by diminishing the relative weight of the ligneous matter, by wasting heat in its evaporation, and by causing slow and imperfect combustion. If a piece of wood contain, for example, 25 per cent. of water, then it contains only 75 per cent. of fuel, and the evaporation of that water will require $\frac{1}{4}$ part of the weight of the wood. Hence the damp wood is of less value in combustion by $\frac{1}{4}$ or $\frac{1}{3}$ than the dry. The quantity of moisture in newly felled wood amounts to from 20 to 50 per cent.; birch contains 30, oak 35, beech and pine 39, alder, 41, fir 45. According to their different natures, woods which have been felled and cleft for 12 months contain still from 20 to 25 per cent. of water. There is never less than 10 per cent. present, even when it has been kept long in a dry place, and though it be dried in a strong heat, it will afterwards absorb 10 or 12 per cent. of water. If it be too strongly kiln dried, its heating powers are impaired by the commencement of carbonisation, as if some of its hydrogen were destroyed.

The following table, compiled from the researches of Count Rumford, will place these points clearly before us.

One pound of the following woods when burnt will heat:	Pounds of water from 0° to 100° Cent.		
	Ordinary condition.	Slightly dried.	Strongly dried.
Lime tree	34·708	38·833	40·131
Beech	33·798	- -	36·746
Elm	30·205	- -	34·083
Oak	25·590	29·210	29·838
Ash	30·666	33·720	35·449
Sycamore	- -	- -	36·117
Fir	30·322	34·000	37·379
Poplar	34·601	- -	37·161

From every combustible the heat is diffused either by radiation or by direct communication to bodies in contact with the flame. In a wood fire the quantity of radiating heat is, to that diffused by the air, as 1 to 3; or it is one fourth of the whole heating power.

II. *Charcoal.*—The different charcoals afford, under equal weights, equal quantities of heat. We may reckon, upon an average, that a pound of dry charcoal is capable of heating 75 pounds of water from the freezing to the boiling point; but when it has been for some time exposed to the air, it contains at least 10 per cent. of water, which is partially decomposed in the combustion into carburetted hydrogen, which causes flame, whereas pure dry charcoal emits none.

Winkler gives the following as the results obtained by him with charcoal from various sources:

Charcoal from:	Pounds of water heated from 0° to 100° Cent. by 1 pound of charcoal.	Air required for perfect combustion.	Pounds of lead reduced by 1 pound of charcoal.
Poplar	On an average 75·7.	On an average 293·5 cubic feet at 19° Cent.	33·56
Sycamore			33·23
Fir			33·51
Ash			33·23
Birch			33·71
Oak			33·74
Elm			33·26
Willow			33·49
Pine			33·53

A cubic foot of charcoal from soft wood weighs upon an average from 8 to 9 pounds, and from hard wood 12 to 13 pounds; and hence the latter is best adapted to maintain a high heat in a small compass. The radiating heat from charcoal fires constitutes one third of the whole emitted.

III. *Turf or peat.* — One pound of this fuel will heat according to its quality, from 18 to 42 pounds of water from freezing to boiling. Its value depends upon its com-

pactness and freedom from earthy particles; and its radiating power is to the whole heat it emits in burning as 1 to 3.

According to Berthier, the following results were obtained from peat: —

Source of the Peat.	Pounds of water heated by 1 pound of peat from 0° to 100° Cent.
From Troyes	18·1
„ department de la Somme	27 9
„ „ de la Marne	29·2
„ „ de la Vosges	34·9
„ „ des Landes	34·6

Winkler gives 26·9 as the evaporative power of the worst Hanoverian peat, and 42·6 as that of the best.

Peat obtained from the Bog of Allen gave, according to Griffith (the discrepancies between the results we do not understand):—

	Pounds of water heated from 0° to 100° Cent.
Upper peat	62·7
Lower peat	56·6
Pressed peat	28·0

IV. *Coal.*— The varieties of coal are almost indefinite, and give out very various quantities of heat in their combustion. The carbon is the heat-giving constituent, and it amounts, in different coals, to from 75 to 95 per cent. One pound of good coal will, upon an average, heat 60 pounds of water from the freezing to the boiling point. Small coal gives out three-fourths of the heat of the larger lumps. The radiating heat emitted by burning pitcoal is greater than that by charcoal.

V. *The coke of coal.* — The heating power of good coke is to that of pitcoal as 75 to 69. One pound of the former will heat 65 pounds of water from 32° to 212°; so that its power is equal to nine-tenths of that of wood charcoal.

Berthier gives as the results of his trials: —

	Pounds of water heated by 1 pound of coal from 0° to 100 C.
Dowlais coal	72·0
Glamorgan	70·7
Newcastle	70·0
Derbyshire	61 6
Lancashire (cannel)	53·2
Durham	71·6
Coke (St. Etienne)	65·6
Do. gas from Paris	50·3

VI. *Carburetted hydrogen or coal gas.* — One pound of this gas, equal to about 24 cubic feet, disengages in burning as much heat as will raise 76 pounds of water from the freezing to the boiling temperature.

In the following table the fourth column contains the weight of atmospherical air, whose oxygen is required for the complete combustion of a pound of each particular substance.

Species of combustible.	Pounds of water which a pound can heat from 0° to 212°.	Pounds of boiling water evaporated by 1 pound.	Weight of atmospheric air at 32°, to burn 1 pound.
Perfectly dry wood	35·00	6·36	5·96
Wood in its ordinary state	26·00	4·72	4·47
Wood charcoal	73·00	13·27	11·46
Pitcoal	60·00	10·90	9·26
Coke	65·00	11·81	11·46
Turf	30·00	5·45	4·60
Turf charcoal	64·00	11·63	9·86
Carburetted hydrogen gas	76·00	13·81	14·58
Oil, Wax, Tallow	78·00	14·18	15·00
Alcohol of the shops	52·60	9·56	11·60

The quantity of air stated in the fourth column, is the smallest possible required to burn the combustible, and is greatly less than would be necessary in practice, where

much of the air never comes into contact with the burning body, and where it consequently never has its whole oxygen consumed. The heating power stated in the second column is also the maximum effect, and can seldom be realised with ordinary boilers. The draught of air usually carries off at least $\frac{1}{4}$ of the heat, and more if its temperature be very high when it leaves the vessel. In this case it may amount to one half of the whole heat, or more; without reckoning the loss by radiation and conduction, which however may be rendered very small by enclosing the fire and flues within proper non-conducting and non-radiating materials.

It appears that, in practice, the quantity of heat which may be obtained from any combustible in a properly mounted apparatus, must vary with the nature of the object to be heated. In heating chambers by stoves, and water boilers by furnaces, the effluent heat in the chimney, which constitutes the principal waste, may be reduced to a very moderate quantity, in comparison of that which escapes from the best constructed reverberatory hearth. In heating the boilers of steam engines, one pound of coal is reckoned adequate to convert $7\frac{1}{2}$ pounds of boiling water into vapour; or to heat $41\frac{1}{4}$ pounds of water from the freezing to the boiling point. One pound of fir of the usual dryness will evaporate 4 pounds of water, or heat 22 pounds to the boiling temperature; which is about two-thirds of the maximum effect of this combustible. According to Watt's experiments upon the great scale, one pound of coal can boil off with the best built boiler, 9 pounds of water; the deficiency from the maximum effect being here $\frac{1}{6}$, or nearly one sixth. See *the Tables at the end of this article.*

In many cases the hot air which passes into the flues or chimneys may be beneficially applied to the heating, drying, or roasting of objects; but care ought to be taken that the draught of the fire be not thereby impaired, and an imperfect combustion of the fuel produced. For, at a low smothering temperature, both carbonic oxide and carburetted hydrogen may be generated from coal, without the production of much heat in the fireplace.

To determine exactly the quantity of heat disengaged by any combustible in the act of burning, three different systems of apparatus have been employed: 1, the calorimeter of Lavoisier and Laplace, in which the substance is burned in the centre of a vessel whose walls are lined with ice, and the amount of ice melted measures the heat evolved; 2, the calorimeter of Watt and Rumford, in which the degree of heat communicated to a given body of water affords the measure of temperature; and 3, by the quantity of water evaporated by different kinds of fuel in similar circumstances.

The first and most celebrated, though probably not the most accurate apparatus for measuring the quantity of heat transferable from a hotter to a colder body, was the calorimeter of Lavoisier and Laplace. It consisted of three concentric cylinders of tin plate, placed at certain distances asunder; the two outer interstitial spaces being filled with ice, while the innermost cylinder received the hot body, the subject of experiment. The quantity of water discharged from the middle space by the melting of the ice in it, served to measure the quantity of heat given out by the body in the central cylinder. A simpler and better instrument on this principle would be a hollow cylinder of ice of proper thickness, into whose interior the hot body would be introduced, and which would indicate by the quantity of water found melted within it the quantity of heat absorbed by the ice. In this case the errors occasioned by the retention of water among the fragments of ice packed into the cylindric cell of the tin calorimeter, would be avoided. One pound of water at 172° Fahr., introduced into the hollow cylinder described, will melt exactly one pound of ice; and one pound of oil heated to 172° will melt half a pound. — *Ure.*

The method of refrigeration, contrived at first by Meyer, has been in modern times brought to great perfection by Dulong and Petit. It rests on the principle, that two surfaces of like size, and of equal radiating force, lose in like times the same quantity of heat when they are at the same temperature. Suppose, for example, that a vessel of polished silver, of small size, and very thin in the metal, is successively filled with different pulverised substances, and that it is allowed to cool from the same elevation of temperature; the quantities of heat lost in the first instant of cooling will be always equal to each other; and if for one of the substances, the velocity of cooling is double of that for another, we may conclude that its capacity for heat is one half, when its weight is the same; since by losing the same quantity of heat, it sinks in temperature double the number of degrees.

The method of mixtures. — In this method two bodies are always employed; a hot body, which becomes cool, and a cold body, which becomes hot, in such manner that all the caloric which goes out of the former is expended in heating the latter. Suppose, for example, that we pour a pound of quicksilver at 212° F., into a pound of water at 32°; the quicksilver will cool and the water will heat, till the mixture by stirring acquires a common temperature. If this temperature was 122°, the water and mercury would have equal capacities, since the same quantity of heat would produce in an equal

mass of these two substances equal changes of temperature, viz., an elevation of 90° in the water and a depression of 90° in the mercury. But in reality, the mixture is found to have a temperature of only 37½°, showing that while the mercury loses 174½° the water gains only 5½°; two numbers in the ratio of about 32 to 1; whence it is concluded, that the capacity of mercury is ⅛ of that of water. Corrections must be made for the influence of the vessel and for the heat dissipated during the time of the experiment.

If our object be to ascertain the relative heating powers of different kinds of fuel, we need not care so much about the total waste of heat in the experiments, provided it be the same in all; and therefore they should be burned in the same furnace, and in the same way. But the more economically the heat is applied, the greater certainty will there be in the results. The apparatus, *fig.* 882, is simple and well adapted to make such comparative trials of fuel. The little furnace is covered at top, and transmits its burned air by *c*, through a spiral tube immersed in a cistern of water, having a thermometer inserted near its top, and another near its bottom, into little side orifices, *a a*, while the effluent air escapes from the upright end of the tube *b*. Here also a thermometer bulb may be placed. The average indication of the two thermometers gives the mean temperature of the water. As the water evaporates from the cistern, it is supplied from a vessel placed alongide of it. The experiment should be begun when the furnace has acquired an equability of temperature. A throttle valve at *c* serves to regulate the draught, and to equalise it in the different experiments by means of the temperature of the effluent air. When the water has been heated the given number of degrees, which should be the same in the different experiments, the fire may be extinguished, the remaining fuel weighed, and compared with the original quantity. Care should be taken to make the combustion as vivid and free from smoke as possible.

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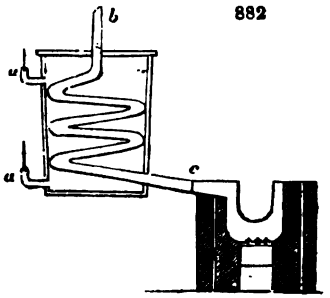

The following calorimeter, founded upon the same principle as that of Count Rumford, but with certain improvements, may be considered as an equally correct instrument for measuring heat with any of the preceding, but one of much more general application, since it can determine the quantity of heat disengaged in combustion, as well as the latent heat of steam and other vapours.

It consists of a large copper bath, *e*, *f* (*fig.* 883), capable of holding 100 gallons of

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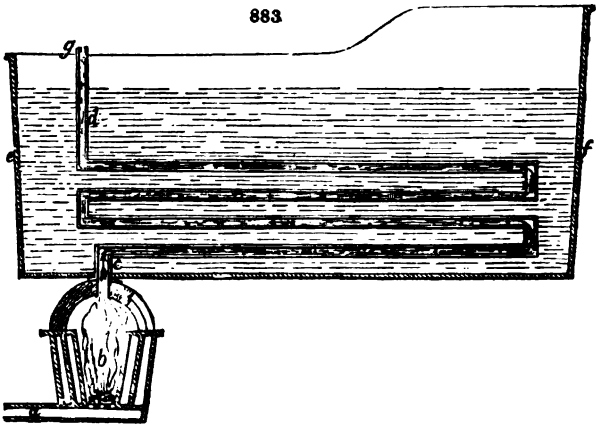

Scale about ¼ inch to the square foot.

water. It is traversed four times, backwards and forwards, in four different levels, by a zig-zag horizontal flue or flat pipe *d*, *c*, nine inches broad and one deep, ending below in a round pipe at *c*, which passes through the bottom of the copper bath *e*, *f*, and receives there into it the top of a small black lead furnace *b*. The innermost crucible contains the fuel. It is surrounded at the distance of one inch by a second crucible, which is enclosed at the same time by the sides of the outermost furnace;

the strata of stagnant air between the crucibles serving to prevent the heat from being dissipated into the atmosphere round the body of the furnace. A pipe *a*, from a pair of cylinder double bellows, enters the ash-pit of the furnace at one side, and supplies a steady but gentle blast, to carry on the combustion, kindled at first by half an ounce of red-hot charcoal. So completely is the heat which is disengaged by the burning fuel absorbed by the water in the bath, that the air discharged at the top orifice *g* has usually the same temperature as the atmosphere.

The vessel is made of copper, weighing two pounds per square foot; it is 5½ feet long, 1½ wide, 2 deep, with a bottom 5½ feet long, and 1¾ broad, upon an average. Including the zig-zag tin plate flue, and a rim of wrought iron, it weighs altogether 85 pounds. Since the specific heat of copper is to that of water as 94 to 1,000, the specific heat of the vessel is equal to that of 8 pounds of water, for which, therefore, the exact correction is made by leaving 8 pounds of water out of the 600 or 1,000 pounds used in each experiment.

In the experiments made with former calorimeters of this kind, the combustion was maintained by the current or draft of a chimney open at bottom, which carried off at the top orifice of the flue a variable quantity of heat, very difficult to estimate.

When the object is to determine the latent heat of steam and other vapours, they may be introduced through a tube into the top orifice *g*, the latent heat being deduced from the elevation of temperature in the water of the bath, and the volume of vapour expended from the quantity of liquid discharged into a measure glass from the bottom outlet *c*. In this case, the furnace is of course removed.

The heating power of the fuel is measured by the number of degrees of temperature which the combustion of one pound of it, raises 600 or 1,000 pounds of water in the bath,—the copper substance of the vessel being taken into account.

It must be borne in mind that a coal which gives off much unburnt carburetted hydrogen gas does not afford so much heat, since in the production of the gas a great deal of heat is carried off in the latent state.

The economy of fuel, as exhibited in the celebrated pumping engines of Cornwall, will be dealt with under the proper head. See STEAM ENGINE. And in reference to the ordinary uses of fuel for domestic and other purposes, see STOVES.

PATENT FUEL. Under this name a great many attempts have been made to utilise waste material. In countries where charcoal is abundant charcoal dust mixed with pitch has been employed, and attempts have been made to utilise the immense quantities of saw-dust produced in the north of Europe, by mixing it with clay and tar. Passing over the several kinds of artificial fuel which have been made on the continent, the productions of this character made in this country must be described.

Wylam's patent fuel is small coal and pitch moulded together into bricks by pressure. The pitch is obtained by the distillation of coal tar from which naphtha and a peculiar oil are separated, leaving the pitch. This pitch is ground fine and mixed with small coal, and in this state it is passed, by a very ingenious application of the Archimedean screw, through a retort maintained at a dull red heat, by which it is softened for being moulded, which is effected by a kind of brick-making machine under enormous pressure.

Warlich's patent fuel is similar in character, but he adds a little common salt or alum to prevent the evolution of too much smoke, and the fuel bricks are subjected to a temperature of 400° F. for eight hours, by which the more volatile constituents are driven off.

Wood's fuel is prepared by mixing small coke or coal in a heated state with tar or pitch in a common pug-mill, after which it is moulded in the ordinary manner.

Bessemer's process consists merely in exposing coal-dust to a temperature of 600° F. By this the bituminous matter of the coal becomes softened, and the whole can be pressed into a firm block.

Grant's patent. This fuel is composed of coal-dust and coal-tar pitch; these materials are mixed together, under the influence of heat, in the following proportions:—20 lbs. of pitch to 1 cwt. of coal-dust, by appropriate machinery, consisting of crushing-rollers for breaking the coal in the first instance sufficiently small so that it may pass through a screen, the meshes of which do not exceed a quarter of an inch asunder; 2ndly, of mixing-pans or cylinders, heated to the temperature of 220°, either by steam or heated air; and, 3rdly, of moulding machines, by which the fuel is compressed, under a pressure equal to five tons, into the size of a common brick; the fuel bricks are then whitewashed, which prevents their sticking together, either in the coal bunkers or in hot climates. The advantages of these artificial fuels over coal may be stated to consist, first, in its efficacy in generating steam; secondly, it occupies less space; that is to say, 500 tons of it may be stowed in an area which will contain only 400 tons of coal; thirdly, it is used with much greater ease by the stokers or firemen than coal, and it creates little or no dirt or dust, considerations of some importance

when the delicate machinery of a steam-engine is considered; fourthly, it produces a very small proportion of clinkers, and thus it is far less liable to choke and destroy the furnace bars and boilers than coal; fifthly, the ignition is so complete that comparatively little smoke, and only a small quantity of ashes, are produced by it; sixthly, from the mixture of the patent fuel, and the manner of its manufacture, it is not liable to enter into spontaneous ignition.

A great many other persons have either patented processes for the preparation of artificial fuel, or published suggestions. These are so nearly alike that a few of them only require any notice.

Cobbold agitates peat in water to separate the earthy matter, and then allows the peat to subside, and consolidates it.

Godwin makes brick of mud or clay with pitch or coal.

Oram employs tar, coals, and mud.

Hill takes the residuary matter after the distillation of peat, and mixes it with pitch.

Holland mixes lime or cement with tar and small coals.

Ransome cements small coal together by a solution of silicate of soda.

From the Admiralty Coal Inquiry's Report we obtain the following analyses of several of the more important artificial fuels: —

Name of Fuel.	Specific Gravity of Fuel.	Carbon.	Hydrogen.	Sulphur.	Oxygen.	Ash.
Warlich's - - -	1·15	90·02	5·56	1·62	- -	2·91
Livingstone's - -	1·18	85·07	4·13	1·45	2·03	4·52
Lyon's - - -	1·13	86 36	4·56	1·29	2·07	4·66
Bell's - - -	1·14	87·88	5·22	0·71	0·42	4·90
Holland and Green's -	1·30	70·14	4·65	- -	- -	13·73
Wylam's - - -	1·10	79·91	5·69	1·25	6·63	4·54

The following returns of trials at Woolwich will place the question of fuel, so far as coal and patent fuel are concerned, in the best possible view.

Report of Trials of Coals at Woolwich Dockyard, between the 9th February, 1848, and the 31st March, 1858.

Description of the Fuel tried.	Number of Trials from which the Average Results are deduced.	Pounds of Water evaporated by 1 lb. Coal from and at 212° Fahr.	Cubic Feet of Water evaporated per Hour, calculated from 1000° constant Temperature of the Feed Water.	Per-centage of Clinker.	Per-centage of Ash.	Per-centage of both Clinker and Ash.	Smoke.
WELSH COALS: —							
Abercarn Black Vein - - -	1	9·01	46·49	1·25	4·46	5·71	No record.
Aberdare Steam Coal - - -	1	8 98	4[illegible]·81	1·72	5·93	7·65	Light smoke.
Ditto Fothergill's - - -	1	9·44	47·6	1·79	4·37	6·16	Light brown smoke.
Ditto Bwllfa - - - -	2	9·4	50·28	1·43	5·75	7 19	Light smoke.
Bedwas - - - - -	1	8·45	45·3	2·08	6·16	8·25	Black smoke.
Birchgrove Graigola - - -	3	8·53	48 37	1·43	9·13	10·55	Nearly smokeless.
Blaendare Big Seam - - -	1	8·28	43·76	3·34	5·1	8·44	Black smoke.
Ditto Merthyr - - -	1	9·06	47·68	3·12	6 14	9·26	Light smoke.
Blaengwaur Merthyr - - -	7	9·38	49·44	1·53	5·84	7·37	Light brown.
Brymbo Main - - - -	2	8·52	44·24	·95	6·4	7·35	No record.
Ditto 2-yard Vein - -	1	8·45	45·[illegible]2	1·13	6·49	7·62	Ditto.
Ditto 4-feet Vein - -	1	8·34	43·03	1·08	5·7	6·78	Ditto.
Ditto Steam Coal - - -	2	7·95	50·47	1·57	4·81	6·4	Black smoke.
Bute Merthyr - - - -	5	9·2	48·59	3·07	5·19	8·26	Light brown.
Camnethan - - - - -	2	8·21	51·91	·55	3·99	4·54	Brown, moderate quantity.
Carr's Merthyr - - - -	3	9·14	49·21	1·[illegible]9	5·23	7·21	Black smoke.
Ch[illegible]rcoal Vein - - -	1	8·98	46·79	1·95	5·06	7·01	No record.
Coed Talon - - - - -	5	7·68	52·11	·96	5·4	6·36	Light smoke.
Coleshill Coal - - - -	1	7·68	52·06	·25	3·11	3·36	No record.
Ditto Bagillt - - - -	2	7·92	49·33	·62	3·57	4·19	Ditto.
Cwm Ammon - - - - -	4	8 6	45·[illegible]2	1·75	3·61	5·36	Light smoke.
Ditto - - - - -	6	8·93	45·93	2·01	5·27	7·28	Ditto.
Cwmfrood Rock Vein - - -	1	8·72	46·88	2·11	4 18	6·29	Black smoke.
Ebbw Vale - - - - -	3	9·26	38·79	1·78	6·78	8 56	Light brown smoke.
Ditto - - - - - -	1	9·09	43·82	2·51	6 41	8·92	No smoke.
Elled's Vein - - - - -	3	9·1	51·21	1 55	5·29	6·84	Brown, large quantity.
Elsecar Hard Steam Coal -	3	8 27	45·99	·73	5·33	6·06	No record.
Eulne Colliery - - - -	2	8·28	48·36	1·31	3·71	5 02	Little smoke.
Garden Edge Colliery Coal -	3	8·41	50·87	·98	5·14	6·12	Black, moderate quantity.

Description of the Fuel tried.	Number of trials from which the Average Results are deduced.	Pounds of Water evaporated by 1 lb. Coal consumed, calculated from 1000 constant Temperature of the Feed Water.	Cubic Feet of Water evaporated per Hour, calculated from 1000 constant Temperature of the Feed Water.	Per centage of Clinker.	Per centage of Ash.	Per-centage of both Clinker and Ash.	Smoke.
Gellia Cadoxtan Steam Coal	2	8·91	49·97	·68	5·7	7·38	Very light smoke.
Ditto Steam Coal	2	8·54	43·83	·87	6·21	9·09	No record.
Golynos	1	9·02	42·62	·69	3·91	5·6	Black smoke.
Graigola Steam Coal	3	8 89	35·59	·42	6 69	8·11	No smoke.
Ditto ditto (handpicked)	1	8·84	41·02	·71	5·52	6·23	No record.
Gwythen Charcoal Vein	1	8·21	47·55	·95	4·4	6·35	Light smoke.
Ditto ditto	4	8·95	48 16	2·7	3·8	6·51	No smoke.
Little Raith Lochgelly	2	7·27	46·68	·92	7·43	8·35	Much light smoke.
Llanelly	1	8·43	46·43	1·96	6·8	8·76	No record.
Llangenneck	2	8·81	46·52	2·36	6·41	8·77	No smoke.
Ditto (handpicked)	2	8·44	44·92	2·03	5·73	7·76	Ditto.
Lochgelly Coal	2	7·66	46·06	·1	4·12	4·22	Light smoke.
Machen Black Vein	1	8·81	50·44	2·1	5·39	7·49	Black smoke.
Machen Rock Vein	1	8·32	47·27	1·37	4·78	6·16	Much black smoke.
Merthyr	28	8·78	45·42	1·02	5·54	6·56	Light smoke.
Ditto	4	9·06	48·17	1·66	4·56	6·23	Ditto.
Ditto Aberamon	1	8·63	47·72	1·45	3·97	5·46	Ditto.
Ditto Aberdare	3	8·75	46·78	1·61	4·06	5·67	No record.
Ditto ditto Fothergill's	43	8·51	44·79	1·47	4·53	6	Light smoke.
Ditto Crosfield	2	9·37	45·14	1·25	6·38	7·63	No record.
Ditto ditto and Gadley's	1	8·66	46·12	·91	7·53	8·44	Ditto.
Ditto (handpicked)	8	8·92	45·84	1·13	4·82	5·95	Light smoke.
Ditto Nixon's	6	8·78	45·54	·98	4·34	5·32	Ditto.
Ditto Wensleydale	1	8·91	45·84	·61	6·49	7·1	No record.
Ditto Wood's	1	8·87	43·7	·67	5·68	6·35	Ditto.
Morfa Steam Coal	1	8·53	44·63	1·12	4 63	5·75	Black smoke.
Ditto ditto Vivian's	2	8·6	44·94	1·3	5·23	6·54	Much black smoke.
Nevill's Llanelly	2	8·56	47·59	2·03	5·8	7·83	Light smoke.
New Black Vein Steam Coal	2	9·56	50·67	·79	5·75	6·54	Large quantity of brown smoke.
Newellino	1	8·97	48·26	2·21	6·25	8·46	No record.
Powell's Duffryn	1	9·08	48·26	1·35	6 81	8·16	Light smoke.
Resolven	9	9·06	48·1	1·77	5·48	7·25	Light brown.
Ditto (handpicked)	1	8·64	45·32	·54	4·35	4·89	No record.
Ditto ditto	1	9·15	49·79	1·75	4·4	6·15	Ditto.
Risca Rock Vein	1	8·26	46·67	1·87	5·22	7 09	Ditto.
Rock Vein	2	8·6	48·11	2·39	5·89	8·28	Ditto.
Squborwen Merthyr	12	8·93	46·51	1·85	6·	7·85	Light smoke.
Thomas' Merthyr	2	9·28	49·99	1·84	4·61	6·45	No record.
Tillery Big Vein	2	8·89	51·99	1·07	4·57	5·64	Ditto.
Wagnus' Merthyr	2	8·79	47·25	1·76	6 48	8 24	Ditto.
Waynes' Merthyr	1	8·98	48·43	1·75	5·22	7·02	Very light smoke.
Welsh Coal	2	9·33	48·62	1·75	6·16	7·92	No record.
NORTH COUNTRY COALS:—							
Alloa Colliery	2	8·89	55·07	1·01	5·02	6·04	Little black smoke.
Atherton Steam Coal	4	8 22	48·76	·74	4·93	5·67	Black smoke.
Barlieth and Dollar's Steam Coal	1	7·95	49·45	·46	4·17	4·63	Black, moderate quantity.
Ditto Steam Coal	4	8·32	49·39	1·29	4·17	5·46	Light brown.
Bates' Hartley	1	6·71	45·66	2·12	4·12	6·24	No record.
Ditto West Hartley	3	7·7	46·41	1·34	5·23	6·56	Black smoke.
Bebside Colliery Coal	4	8·14	49·82	·95	4·6	5·55	Ditto.
Bell's Primrose	3	9·46	45·67	2·4	6·68	9·08	No record.
Bourtreehill Coal	1	7·56	45·96	1·27	4·67	5·94	Much smoke.
Buddle's Hartley	23	7·79	47·98	1·49	4·08	5·58	Dark smoke.
Ditto West Hartley	38	8·05	48·34	1·41	4·47	5·87	Black smoke.
Carr's Hartley	9	8·05	48·63	1·71	3·76	5·47	Black, large quantity.
Clackmannan	3	8·09	45·39	·67	4·76	5·43	Black smoke.
Cuttlehill	1	7·72	42·57	-	5·74	-	No record.
Derwentwater, Radcliffe Colliery	1	8·27	50·22	1·1	3·8	4·93	Black smoke.
Ditto West Hartley	1	7·69	48·23	1·67	4·72	6 39	No record.
Earsdon's Hartley	3	8·25	50·12	·71	4·88	5·59	Great quantity of black smoke.
Garforth's Hartley	2	8·06	50·11	·61	5·75	6·36	Heavy smoke.
Garforth Steam Coal	2	7·12	40·33	1·26	5·6	6·86	Light smoke.
Garswood Park	1	7·99	51·61	1·19	5·29	6·48	No record.
Gawber Hall	2	8·14	42·49	1·05	4·11	5·16	Ditto.
Ditto Steam Coal	5	7·84	43·01	1·25	5·8	7·05	Light smoke.
Gower Coal	2	7 83	44·58	·92	5·28	6·21	Black smoke.
Grey's Broomhill	5	8·04	48·87	1·14	5 66	6·79	Heavy black smoke.
Grimsby Coal, Sheffield Railway	1	7·46	45·84	1·69	4·24	5·93	No record.
Halsnead Coal	3	7·48	47·23	1·24	3·69	4·93	Dark smoke.
Hartley Coal	2	7·74	45·78	1·06	5·77	6·83	No record.
Ditto Bates' West	1	7·39	48·27	·66	7·07	7·73	Heavy black smoke.
Ditto Belmont	2	8·4	46·3	1·43	3·97	5·41	No record.
Ditto Buddle's	4	7·8	45·61	1·15	4·11	5·27	Much smoke.
Ditto ditto West	17	7·82	46·33	1·28	4·09	5·38	Black smoke.
Ditto Carr's	15	8·19	45·45	1·22	3·93	5·14	Dark smoke.
Ditto ditto West	1	8·35	48·43	1·	5·88	6·88	Heavy black.

Description of the Fuel tried.	Number of Trials from which the Average results are deduced.	Pounds of Water evaporated to 1 lb. Coal consumed, calculated from 100° constant Temperature of the Feed Water.	Cubic Feet of Water evaporated per Hour, calculated from 1000 constant Temperature of the Feed Water.	Per-centage of Clinker.	Per-centage of Ash.	Per-centage of both Clinker and Ash.	Smoke.
Hartley, Clifton's West	3	7·91	45·02	1·48	4·57	6·05	Ditto.
Ditto Cowpen	2	7·63	44·87	·73	5·94	6·68	No record.
Ditto Fenham's	21	8·53	43·47	2·07	5·1	7·17	Heavy black.
Ditto ditto West	1	8·87	42·41	2·89	6·25	9·14	Ditto.
Ditto Hedley's	1	8·4	47·02	1·29	2·91	4·2	No record.
Ditto Hetton West	3	8·45	47·39	1·18	6·98	8·16	Ditto.
Ditto Howard's West Netherton	2	7·67	46·22	1·35	6·8	8·15	Ditto.
Ditto Jonassohn's	4	8·09	49·12	·88	5·34	6·23	Little black smoke.
Ditto Longridge West	1	7·82	47·57	1·46	3·75	5·21	No record.
Ditto ditto Best	2	7·86	46·1	1·18	3·39	4·57	Light smoke.
Ditto Morpeth	6	7·87	47·58	1·52	4·7	6·22	Little black smoke.
Ditto Newcastle	2	8·49	45·41	2·07	5·73	7·81	No record.
Ditto Wellington West	1	8·89	42·18	1·37	5·09	6·46	Black smoke.
Ditto Whitworth	2	8·4	42·88	1·79	3·81	5·61	Ditto.
Ditto Willington West	1	8·93	43·11	1·35	3 65	5·	No record.
Hastings Hartley	1	7·73	47·45	1·16	3·94	5·1	Heavy black smoke
Heaton Colliery	3	8 79	46 2	2·38	6 29	8·67	Much smoke.
Howard's West Hartley	17	8·08	49·58	1 24	4·69	5·93	Dark smoke.
Ditto Netherton	6	9·58	58·36	2 22	5·14	7·36	Ditto.
Hoyland Colliery	2	8·7	48·98	·55	3·95	4·5	Black smoke.
Ditto and Elsecar	3	8·15	45·78	·67	4·12	4·79	No smoke.
Ince Hall Coal	2	7·72	45·22	1·44	5 4	6·85	Very smoky.
Ditto	1	8·04	45·62	1·08	3·76	4·84	No record.
Kilnhurst Hard	1	7 74	45·77	1·21	3·24	4·45	Much black smoke.
Land Engine Coal	1	7·86	48·09	1·51	4·68	6·19	No record.
Lindsay Mine	2	7·9	42·86	2·04	2·83	4·88	Ditto.
Lord Hosslyn's Coal	1	6·11	42·66	1·67	6·08	7·75	Black smoke.
Lord Ward's Steam Coal	2	7·6	51·3	1·36	4·37	5·74	Brown, in moderate quantity.
Lumley's Steam Coal	2	8·54	37·4	1·01	6·63	7·64	No record.
Lundhill Hard Coal	2	8·84	49·19	1·22	3·92	5·14	Black, in great quantity.
Ditto Soft ditto	3	8·55	50·42	1·6	3·87	5·47	Ditto ditto.
Lyon's West Hartley	4	8·71	52·73	1·17	4·95	6·12	Black smoke.
Midgeholme	2	9 25	44·26	·59	6·16	6·76	No record.
North Country Coal	1	8·16	50·14	1·47	5·03	6·5	Heavy black smoke
North Gawber Steam Coal	1	7·71	45 04	·85	4·59	5·44	No record.
Oaks Colliery	4	7·75	44·91	·42	6·03	6·46	Heavy smoke.
Orrell Steam Coal	2	8·78	42·61	1·54	6·82	8·37	No record.
Ramsay's Adair's Main	3	8·65	43·1	1·01	5·35	6·36	Light brown.
Ravensworth's Hartley	3	7·77	48·44	1·63	4·79	6·4	Heavy black smoke
Rochsole's Colliery	3	7·76	46·54	1 67	2·82	4·49	Light smoke.
Skerrington Coal	3	7·81	47·6	1·02	3·63	4·66	Much smoke.
Ditto Colliery	2	8·69	52·45	1·67	5·73	7·41	Light smoke.
Splint Coal	3	7·25	42·29	·67	4 2	4·87	Ditto.
St. Helen's Tees	3	9·19	54 15	·33	4·78	5·11	Black, in large quantity.
Staveley Main Coal	3	7·09	41 27	·71	4·26	4·96	Light smoke.
Strangeways, Colliery, 3-ft. Seam	1	7·91	48 17	·87	5 28	6·15	Black, in small quantity.
Walthen House, or New House	1	8·62	49·11	2·85	5·07	7·92	No record.
Washington's West Hartley	2	8·63	48·26	2·91	5·98	8·89	Black smoke.
Wather House Steam Coal	4	7·84	47·75	2·46	3·61	6·11	No record.
Wellington Hartley	1	7·84	49·92	1·51	4·09	5·6	Black smoke.
Wellwood Colliery	2	7 97	50·25	1·05	7·05	8·1	Heavy black smoke.
West Hartley	2	8·08	47·97	1·79	4 46	6 25	Heavy smoke.
Whitefield Colliery	2	9·49	52·17	·05	4·42	4·47	Little brown smoke
Whitworth Park	2	8·79	46·49	·92	5·14	6·07	No record.
Wigan, 4-feet Seam	1	7·97	45 38	1·64	5·75	7 39	Ditto.
Wombwell Main	3	8·26	44·89	·81	4 5	5·31	Ditto.
Yate Deep Vein	3	8·26	51·11	3·1	4·47	7·57	Much black smoke
ANTHRACITE COAL	2	9·58	35·43	1·48	10·32	11·81	No record.
Ditto	4	6·87	26·64	·18	2·42	2·6	Nearly smokeless.
Ditto Bonville's Court	3	8·35	31·19	1·02	5·57	6 59	No record.
Ditto Killgetty	6	9·02	42·68	·64	11·3	11·94	Ditto.
Ditto Watney's	4	8·87	41·44	1·48	6·58	8·06	Smokeless.
CAMBRIAN STEAM FUEL	3	8·32	45·45	1·17	5·81	6 98	
CHILIAN COAL	1	7·29	38 83	2·8	3 33	6·13	Light smoke.
COKE CONSOLIDATED	2	8·76	19·47	·14	19·11	19·25	No record.
PATENT FUEL	1	8·59	48·85	1·97	4·21	6·18	Ditto.
Ditto	3	9·11	48 2	2·4	3·86	6·26	Black smoke.
Ditto Captain Cochrane's	1	4·01	22·09	7·76	32·5	40·26	No record.
Ditto Holland's	6	7·94	39·51	1·7	6 3	8·	Light brown.
Ditto Lyon's	2	8·98	47·4	2·86	4·37	7·24	No record.
Ditto Temperly's	3	8·5	42·45	·99	7·19	8·19	Ditto.
Ditto Warlich's	8	8·7	44 12	2·4	7·64	10 04	Little brown smoke
Ditto ditto	4	9·16	46·47	3·03	5·62	8·65	No record.
PORT ADELAIDE	1	6·44	32·3	7·42	23 35	30 77	No smoke.
SINGAPORE COAL	1	6·97	48 77	-	9·99	-	No record.
ST. DOMINGO (Samana)	1	1·29	10·59	-	18·	18·	Little smoke.

FULGURATION designates the sudden brightening of the melted gold and silver in the cupel of the assayer, when the last film of vitreous lead and copper leaves their surface.

FULLER'S EARTH. (*Terre à foulon, Argile, Smectique*, Fr.; *Walkererde*, Germ.) In geology this term is applied to the clayey deposit which intervenes between the calcareous strata commonly known as the Bath or Great Oolite, and the Inferior Oolite. A sandy argillaceous earth is met with in the upper part of the clay in question, to which the name Fuller's earth was given from its adaptability for *fulling* or cleansing cloth, when first woven, from grease and other impurities. The term thus limited originally to a particular stratum was subsequently applied to the entire formation by Dr. William Smith in his classification of the British strata, and has ever since retained its place in geological nomenclature. The fuller's earth above mentioned was formerly procured in considerable quantities from the Downs, to the south of Bath, whence it was sent to the cloth factories of Gloucestershire. Of late years, however, an artificial substitute has been found in a chemical preparation, and the demand for the natural production has decreased so far, that little or none of it is now procured in the West of England. The fuller's earth of Reigate is found in strata of a much more recent date than those alluded to above, and forms a part of the Lower Greensand. — See GREENSAND.

From Reigate 12,000 tons of dried fuller's earth are raised annually. There are two varieties, called the blue and yellow; their analyses are respectively —

	Blue.	Yellow.
Alumina	18	11
Silica	42	44
Lime	4	5
Magnesia	2	2
Oxide of Iron	6	10
Soda	5	5

The other places from which fuller's earth has been obtained, are — Penenden Heath, Maidstone, Frome, Lonsdale, Coombe Hay, English Coombe, and Duncorn Hill in Gloucestershire, and at one locality in Bedfordshire. — H. W. B.

FULLING. The art of cleansing, scouring, and pressing woollen manufactures. The object is to render them stronger and firmer. It is called also *milling*, because the cloths are scoured by a water mill.

The principal parts of a fulling mill, are the wheel with its trundle, which gives motion to the tree or spindle whose teeth communicate that motion to the stampers or beaters, which fall into troughs, wherein the cloth is put, with the fuller's earth.

William and Ogle introduced in 1825 some new fulling machinery, designed to act in a similar way to the ordinary stocks, in which cloths are beaten, for the purpose of washing and thickening them; but the standard and the bed of the stocks are made of iron instead of wood, as heretofore; and a steam vessel is placed under the bed, for heating the cloths during the operation of fulling; whereby their appearance is said to be greatly improved.

Fig. 884 is a section of the fulling machine or stocks; *a*, is a cast-iron pillar, made hollow for the sake of lightness; *b*, is the bed of the stocks, made also of iron, and polished smooth, the side of the stock being removed to show the interior; *c*, is the lever that carries the beater *d*. The cloths are to be placed on the bed *b*, at bottom, and water allowed to pass through the stock, when by the repeated blows of the beater *d*, which is raised and let fall in the usual way, the cloths are beaten, and become cleansed and fulled.

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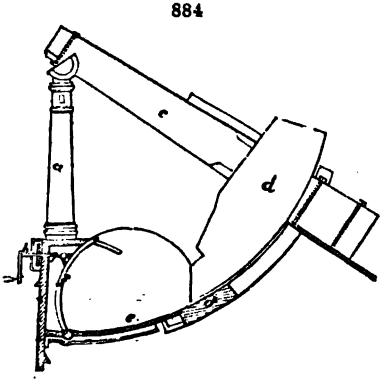


A part of the bed at *e* is made hollow, for the purpose of forming a steam box, into which steam from a boiler is introduced by a pipe with a stop-cock. This steam heats the bed of the stock, and greatly facilitates, as well as improves, the process of cleansing and fulling the cloths.

The smoothness of the surface of the polished metal, of which the bed of the stock is constituted, is said to be very much preferable to the roughness of the surface of wood of which ordinary fulling stocks are made, as by these iron stocks less of the nap

or felt of the cloth is removed, and its appearance when finished is very much superior to cloths fulled in ordinary stocks.

In the operation of fulling, the cloths are turned over on the bed by the falling of the beaters, but this turning over of the cloths will depend in a great measure upon the form of the front or breast of the stock. In these improved stocks, therefore, there is a contrivance by which the form of the front may be varied at pleasure, in order to suit cloths of different qualities; *f*, is a movable curved plate, constituting the front of the stock; its lower part is a cylindrical rod, extending along the entire width of the bed, and being fitted into a recess, forms a hinge joint upon which the curved plate moves; *g*, is a rod attached to the back of the curved plate *f*, with a screw thread upon it; this rod passes through a nut *h*, and by turning this nut, the rod is moved backward or forward, and consequently, the position of the curved plate altered.

The nut *h*, is a wheel with teeth, taking into two other similar toothed wheels, one on each side of it, which are likewise the nuts of similar rods jointed to the back of the curved plate *f*; by turning the central wheel, therefore, which may be done by a winch, the other two wheels are turned also, and the curved plate moved backward or forward. At the upper part of the plate there are pins passing through curved slots, which act as guides when the plate is moved.

FULMINATING MERCURY, $C^4N^2Hg^2O^4 + Ag$. (dried at 212°). The well known compound used for priming percussion caps. It was analysed many years ago by Liebig, and subsequently, by Gay-Lussac. Although chemists have long been acquainted with the true composition of fulminic acid, and the formula of fulminating mercury has also been rendered almost certain, no accurate analysis of the latter compound was made public until 1855, when M. Schischkoff published his celebrated paper on the fulminates. It is singular that Liebig and Schischkoff were independently engaged at the same time in investigating the products of decomposition of the fulminates. The formula of fulminic acid, and also that of fulminating mercury, had been deduced from the very accurate analysis of fulminating silver made by Gay-Lussac and Liebig. A great number of processes for the preparation of fulminating mercury have been published. The following are the best as regards economy and certainty.

1. One part of mercury is to be dissolved in 10 parts of nitric acid, sp. gr. 1·4, and the solution at a temperature of 130° F. is to be poured into 8·3 parts of alcohol, sp. gr. 0·830. — *Dr. Ure.*

2. One part of mercury is to be dissolved in 12 parts of nitric acid, of sp. gr. 1·3. To the solution (as soon as it has cooled to 55° F.), 8 parts of alcohol, sp. gr. 0·837, are to be added; the vessel containing the mixture is to be heated in boiling water until thick white fumes begin to form. The whole is then set in a cool place to deposit the crystals of fulminate. — *Cremascoli.*

3. One part of mercury is to be dissolved in 12 parts of nitric acid, sp. gr. 1·340 to 1·345, in a flask capable of holding 18 times the quantity of fluid used. When the metal is dissolved, the solution is decanted into a second vessel containing 5·7 parts of alcohol, of 90° to 92° (*Tralles*), then immediately poured back into the first vessel, and agitated to promote absorption of the nitrous acid. In five to ten minutes gas bubbles begin to rise, and there is formed at the bottom of the vessel a strongly refracting, specifically heavier liquid, which must be mixed with the rest by gentle agitation. A moment then arrives when the liquid becomes black from separation of metallic mercury, and an extremely violent action is set up, with evolution of a thick white vapour, and traces of nitrous acid; this action must be moderated by gradually pouring in 5·7 parts more of the same alcohol. The blackening then immediately disappears, and crystals of fulminating mercury begin to separate. When the fluid has become cold, all the fulminating mercury is found at the bottom. By this method not a trace of mercury remains in solution. — *Liebig.*

The fulminate in all these processes is to be collected on filters, washed with distilled water, and dried. The violent reaction which takes place when the solution of mercury reacts on the alcohol is essential to the success of the operation.

With regard to the economy of the above methods, it has been found that 1 part of mercury yields the following proportions of fulminate: —

1st process	1·30
2nd „	1·25
3rd „	1·53

C. G. W.

FULMINATING SILVER, $C^4Ag^2N^2O^4$. This salt corresponds in constitution to the fulminate of mercury; it may also be prepared by analogous processes, merely substituting silver for mercury. *Preparation.*—1. 1 part of silver is to be dissolved in 24 parts of nitric acid, sp. gr. 1·5, previously mixed with an equal weight of water.

To the solution is to be added alcohol equal in weight to nitric acid. *Produce*, 1·5 parts of fulminating silver. 2. 1 part of silver is to be dissolved in 20 parts of nitric acid, sp. gr. 1·38. To the solution is to be added 27 parts of alcohol, sp. gr. 0·832. The mixture is to be heated to boiling, and, as soon as it shows signs of becoming turbid, it is to be removed from the fire, and a quantity of alcohol, equal in weight to the first, is to be poured in. The liquid is now to be allowed to become perfectly cold, when the fulminate will be found at the bottom of the vessel. *Produce*, equal to the silver employed. 3. 1 part of silver is to be dissolved in ten times its weight of nitric acid, sp. gr. 1·36. To the solution is to be added 20 parts of alcohol, sp. gr. 0·83. The mixture is to be treated as in the second mode of preparation, except that no more alcohol is to be added. The produce should be in fine crystals. Whichever mode of preparation be selected, it is absolutely necessary, in order to avoid fearful accidents, that the following precautions be attended to. The beakers or flasks employed must be two or three times larger than is required to hold the ingredients, for if, owing to frothing or boiling over, any of the fluid happened to find its way to the outside, and dry there, an explosion might ensue. Care must also be taken that the highly inflammable vapours given off during the preparation do not come near any flame. The salt, when formed, must be received on a filter, and well washed with cold water. It is safer to dry it spontaneously, or over oil of vitriol, for although it will endure a heat above that of boiling water before exploding, yet when warm, the slightest touch with a hard substance is often sufficient to cause a terrible detonation. A spatula of pasteboard or very thin wood should be employed to transfer it into its receptacle. Fulminating silver should not be kept in glass vessels, for fear of the salt finding its way between the cork or stopper, the slightest movement with a view of opening the vessel, being then sufficient to cause an accident. Small paper boxes are the safest to keep it in.

Fulminating silver gives a more violent detonation than the corresponding mercurial compound. The presence of roughness or granular particles on the substances with which it may be in contact, assists greatly in causing it to explode.

Although giving so violent an explosion when alone, it may be burnt without danger when mixed with a large excess of oxide of copper, as in the ordinary process of organic analysis. It then gives off a mixture of two volumes of carbonic acid, and one volume of nitrogen. Gay-Lussac and Liebig made an analysis of the salt in this manner, with the annexed results: —

	Experiment.		Calculation.		
Carbon	7·9	C^4	24	8·0
Nitrogen	9·2	N^2	28	9·3
Silver	72·2	Ag^2	216	72·0
Oxygen	10·7	O^4	32	10·7
	100·0		300	100·0

For further remarks on the fulminates, see Fulminating Mercury.—C. G. W.

FULMINIC ACID, $C^4N^2H^2O^4$. The acid contained in fulminating mercury; which see.

FUMIGATION is the employment of fumes or vapours to purify articles of apparel, and goods or apartments supposed to be imbued with some infectious or contagious poison or fumes. The vapours of vinegar, the fumes of burning sulphur, explosion of gunpowder, have been long prescribed and practised, but they have in all probability little or no efficacy. The diffusion of such powerful agents as chlorine gas, muriatic acid gas, or nitric acid vapour, should alone be trusted to for the destruction of morbific effluvia. See Disinfectants.

FUR. (*Fourrure*, Fr; *Pelz*, Germ.) Fur may be strictly distinguished as the short fine soft air of certain animals, growing thick on the skin, and distinguished from the hair which is longer and coarser. The term is, however, used sometimes very loosely, and includes those skins which are covered with hair. Fur is one of the most perfect non-conductors of heat, and consequently we find the animals of the colder regions of the earth clothed with this substance, and hence man has adopted it as the warmest of clothing.

To the admirable report made by Messrs. J. A. Nicholay and James B. Bevington, on the furs of the Great Exhibition, we are mainly indebted for the following particulars.

The Russian Sable (*Mustela zibellina*). In the reign of Henry VIII., by a law to regulate the expenses of different classes, and to distinguish them by peculiarity of costume, the use of sable was confined to the nobility above the rank of viscount. It is stated that 25,000 skins are annually collected in the Russian territories. The fur is brown, with some grey spots on the head; the darker varieties are the most valuable, a single skin of a fine dark colour being sold for as much as nine pounds, though the

average value does not exceed two or three. The Russian sable is sometimes confounded with the Hudson's Bay sable, but to the furrier the former is easily distinguishable from the length and fullness, as well as the darker colour, of the fur.

HUDSON'S BAY SABLE (*Mustela Canadensis*). As the natural colour of this skin is much lighter than the prevailing taste, it is the practice to dye many of them a darker colour, and the furs thus treated are scarcely inferior to the Russian or true sable. Not less than 120,000 skins are annually imported into this country.

PINE MARTEN or BAUM (*Mustela abietum*). The animals producing this skin are found in extensive forests in the north of Europe. The skins are distinguished from the stone martin by the yellow colour of the throne. These skins are dyed to imitate real sable.

STONE MARTEN (*Mustela saxorum*). This is frequently called French sable, from the fact that the French furriers excel in dyeing this skin. The stone marten is distributed through most European countries. The under fur is a bluish white, with the top hairs a dark brown, the throat being generally a pure white, by which it is distinguished.

FISHER. These skins are larger than the sables, and the fur is longer and fuller; about 11,000 of these skins are annually brought from America. The tail, which is long, round, and gradually tapering to a point, was formerly used as the common ornament to a national cap worn by the Jew merchants of Poland.

MINK (*Mustela vison*). There were 245,000 skins of this little animal brought to this country in 1850. The fur resembles sable in colour, but is considerably shorter and more glossy.

ERMINE (*Mustela erminea*). This animal is similar in form and habit to the common weasel of this country, but in Siberia, Russia, and Norway, from whence the skins are imported; the little animal during winter becomes as white as the snowy regions it inhabits, and is esteemed the whitest fur known, though in summer its dress is a dingy brown. The tail of the skin, of which the lower half is jet black is usually introduced as an ornament to the purely white fur. In Edward III.'s reign, the use of ermine was restricted to the royal family.

FITCH or POLECAT (*Mustela putorius*), produced throughout Europe and in our own country. This animal has a soft black fur with a rich yellow ground. The natural smell of this fur is unpleasant and difficult to overcome.

NORTH AMERICAN SKUNK (*Mephitis Americana*). These skins are imported by the Hudson's Bay Company. The animal from which it is obtained is allied to the polecat of Europe. The fur is a soft black, with two white stripes running from the head to the tail. This fur is not much used in this country.

KOLINSKY (*Mustela Siberica*). The Tartar sable, which is of a bright yellow colour. It is sometimes used in its natural state, but is more frequently dyed brown to imitate other sable, to which it bears a strong resemblance. It is remarkable for the uniformity of its colour, having no spot or difference of shade in any part of the body. The tail which is of the same colour, is exclusively used for the best artist's pencils.

MUSK RAT or MUSQUASH (*Fiber zibethicus*), an inhabitant of the swamps and rivers of America. About a million skins are brought to this country annually. The fur resembles that of the beaver, and was used by hat manufacturers. The skins are also dyed by the furrier, and manufactured into many cheap and useful articles.

NUTRIA or COYPON (*Myopotamus coypus*). This animal is larger than, but somewhat similar to, the musquash; it inhabits the banks of rivers in Buenos Ayres and Chili. But few of these skins are now imported.

HAMSTER (*Cricetus vulgaris*), a native of Germany, where not less than 100,000 skins are annually collected. It has a poor, short, and coarse fur, which is almost exclusively used for cloak linings by the Greeks. The colour of the back is a reddish brown, the belly black, with a few light spots.

PERWITZKY. The skin of this animal is marked like tortoise shell; it is brought from the southern extremities of Asiatic Russia. It is chiefly used by the Russians for cloak lining.

BEAVER (*Castor Americanus*). This beautiful fur is sometimes used for articles of dress. In order to prepare the skin for this appropriation, the coarse hairs are removed, and the surface cut by a very ingenious machine, somewhat similar to that used in dressing cloth. The skin thus prepared has a beautiful appearance, not unlike the costly South Sea otter, and has the advantage of durability and lightness.

OTTER (*Lutra vulgaris, Lutra Canadensis*). Of the British otter about 500 skins are collected annually. The large quantity used by the Russians and Chinese is derived principally from North America.

SEA OTTER (*Enhydra marina*). The sea otter has a very thick, soft, woolly fur, and is most highly prized by the Russians and Chinese, to whom most of the skins

are exported. The animal is found in the North Pacific from Kamtschatka to the Yellow Sea, on the Asiatic coasts, and from Alaska to California on the American coasts.

SEAL (*Phoca*). There are numerous varieties of these animals, which are found on the western coasts of these islands, and in immense numbers on the shores of Labrador, Greenland, and Newfoundland. The greater portion of the skins imported are tanned and enamelled with black varnish for ladies' shoes; other descriptions are well adapted for fur. Before they can be used as a fur, it is necessary to remove the very coarse hairs which cover a beautifully fine and silky fur. By shaving the felt to half its natural substance, the roots of the coarse hairs are cut through, and they easily fall out, but the same effect is produced by the natural process of fermentation, which ensues when the skins are properly prepared and allowed to remain together. This fur is rarely used in its natural state, but is dyed a deep vandyke brown, when it has the appearance of the richest velvet.

The skins of the fox, the wolverine (*Gulo luscus*), the bear, the hare, and the rabbit, scarcely require notice.

The SQUIRREL, especially the Siberian squirrel, is much sought for. It is said that 15,000,000 of these skins are annually collected in Russia, and of these, 3,000,000 are sent to this country.

CHINCHILLA (*Chinchilla lanigera*). There are two varieties of Chinchilla, the produce of South America. Our chief supply is from Buenos Ayres and Arica. The skins from the former locality are of a silvery grey. Those from Arica are the darkest and best coloured skins.

RACCOON (*Procyon totor*), this fur is used for lining coats.

CAT (*Felix domesticus*). In Holland, the cat is bred for its fur; it is fed on fish and carefully tended until the fur arrives at perfection.

CANADA LYNX (*Felix Canadensis*). This fur is not much used in this country, but it is prepared and exported for the American market.

Number of Skins and Furs imported in the years 1853 *to* 1857.

	1853.	1854.	1855.	1856.	1857.
Skins: —	No.	No.	No.	No.	No.
Sheep and lamb -	3,372,855	3,410,161	1,806,001	3,084,683	3,685,633
Goat - - -	661,084	911,925	503,918	1,218,548	1,158,277
Kid - - -	887,426	726,004	695,859	453,810	402,600
Seal - - -	850,550	661,552	601,002	681,234	803,438
Furs: —					
Marten - -	134,671	193,418	222,153	206,777	157,319
Mink - - -	184,529	200,205	167,981	113,046	146,640
Raccoon - -	475,858	505,445	394,655	498,121	492,159
All other skins and furs - -*		286,126	273,764	448,049	438,379

Total Value of Skins and Furs imported in the years 1854 *to* 1857.

	1854.	1855.	1856.	1857.
	£	£	£	£
Skins and furs - - - -	1,017,453	941,855	1,436,969	1,422,974

Number of Skins and Furs exported in the years 1853 *to* 1857.

	1853.	1854.	1855.	1856.	1857.
Skins: —	No.	No.	No.	No.	No.
Sheep and lamb -	36,368	334,622	221,759	317,391	271,825
Goat - - -	240,945	285,548	128,659	265,438	399,140
Kid - - -	43,749	25,347	17,593	4,894	19,841
Seal - - -	12,163	18,011	1,995	3,695	5,721
Furs: —					
Marten - - -	29,677	24,253	29,476	46,367	89,038
Mink - - -	74,309	61,557	78,744	46,749	84,781
Raccoon - -	483,893	507,047	523,928	380,870	485,528
All other skins and furs - -		115,166	141,415	225,904	228,620

* Not ascertained previously to the year 1854.

Total Value of Skins and Furs exported in the years 1854 *to* 1857.

	1854.	1855.	1856.	1857.
	£	£	£	£
Skins and furs - - -	247,549	270,807	396,561	489,784

Quantities and Value of Skins and Furs exported in the year 1857.

	Quantities.			Value.		
	British Produce.	Foreign and Colonial Produce.	Total.	British Produce.	Foreign and Colonial Produce.	Total.
Skins:—	No.	No.	No.	£	£	£
Beaver - - -	...	87,440	87,440	...	41,534	41,534
Goat - - -	102,503	399,140	501,643	9,309	41,852	51,161
Fox - - - -	...	80,582	80,582	...	66,144	66,144
Musquash - -	584,705	448,240	1,032,945	35,872	23,345	59,217
Raccoon - - -	...	485,528	485,528	...	91,036	91,036
Sheep and lambs -	1,613,761	271,825	1,885,586	78,682	16,929	95,549

Quantities and Value of Skins exported in the year 1857.

	Quantities.	Computed Real Value.		Quantities.	Computed Real Value.
Skins:—	No.	£	Skins:—	No.	£
Bear - - -	7,917	14,844	Marten - -	89,038	72,343
Cat - - -	4,570	1,066	„ tails -	1,830	46
Chinchilla - -	24,793	1,679	Mink - -	84,781	33,559
Coney - -	18,016	375	Nutria - -	36,436	2,012
Deer - - -	43,607	8,684	Otter - - -	10,346	15,390
Dog - - -	144	1	Pelts - - -	560	5
Dogfish - -	397	17	Sable - - -	124	320
Elk - - -	28	21	„ tails -	270	27
Ermine - -	920	103	Seal - - -	5,721	2,336
Fisher - -	8,112	12,337	Squirrel - -	550	7
Fitch - - -	3,605	496	„ tails -	...	502
Hare - - -	40,835	936	Swan - -	250	32
Kid - - -	19,841	3,109	Tiger - -	7	12
Kolinsky - -	1,503	263	Wolf - - -	5,715	2,715
Leopard - -	29	43	Wolverines -	658	493
Lion - -	22	22	Unenumerated -	...	17,663
Lynx - -	27,251	17,486			

The importance of the trade in furs and skins will be rendered evident from the preceding accounts of the Imports and Exports. It would have been desirable to have separated the furs, strictly so called, from the skins, but this has not been found practicable with anything like accuracy; the returns are therefore given under the heads adopted by the Customs.

Furs are subject to injury by several species of moths, whose instinct leads them to deposit their eggs at the roots of the fine hair of animals.

Linnæus mentions five species that prey upon cloth and furs, of which *Tinea pellionella*, *T. vestionella* and *T. tapelzella* are the most destructive. No sooner is the worm hatched than it eats its path through the fur, and continues increasingly destructive until it arrives at its full growth, and forms itself a silken covering, from which, in a short time, it again emerges a perfect moth.

Another cause of the decay of fur is, the moisture to which they are frequently exposed; the delicate structure of the fine under fur cannot be preserved when any dampness is allowed to remain in the skin. This fact is well known to the leather manufacturer, who, having wetted his skins, allows them to remain in a damp cellar

for a few days, for the purpose of removing the hair which is pulled out with the greatest facility, after remaining only one week in a moist condition. It follows from these observations, that to preserve the fur it is necessary to keep them dry, and to protect them from moths; if exposed to rain or damp, they must be dried at a moderate distance from the fire; and when put by for the summer should be combed and beaten with a small cane, and very carefully secured in a dry brown paper or box, into which moths cannot enter. During the summer they should be examined once a month to be again beaten and aired, if the situation in which they have been placed be at all damp. With these precautions, the most valuable furs may be preserved uninjured for many years.

FURNACE. The various descriptions of furnaces employed in the different metallurgical processes will be found described in the articles devoted to the metals. See BRASS, COPPER, &c. &c., and METALLURGY.

FUR-SKIN DRESSING. Fur-skins are usually dressed by placing them in their dried state in closed tubs with a little salt butter, where they undergo a treading operation with men's feet until they are sufficiently soft, and bend easily. The skins if large are sewn up, the fur being turned inwards; but if small skins, such as ermine, are being dressed, they require no sewing. This sewing is preparatory to the greasing with butter or lard, and is intended to protect the fur from the grease, and to promote the softening in the succeeding treading operation. The skins are next wetted, and their flesh is removed; or they are fleshed. See CURRYING. They are again subjected to treading in tubs containing sawdust, that from mahogany being preferred; and afterwards in tubs containing plaster of Paris, or whitening, sprinkled between the skins. The main object of this is to remove the grease which has been used in the previous processes. They are then beaten with a stick, and combed; when the dressing is completed. M. Pierre Thirion proposed to soften the skins, not by treading, but by beating stocks, of a construction like the fulling mill. They are next sewn up, and again filled in a strong vessel, where they are forced upwards by the beaters, turned over and over, and thus speedily softened. They are now fleshed, and then returned to the beating stocks, and mahogany or other sawdust is sprinkled upon the fur, before the beating is renewed. They are next placed in a heated barrel, furnished within with radial pins for turning the goods over and over, in order that they may be acted upon by various dry substances, which are thrown into the barrel, and absorb the fat from the skins. Through the hollow shaft of the barrel steam is introduced, which heats the skins, softening the fat, which is then absorbed by sand, flour, or any other desiccative powder. It is proper to take the skins out of the barrel from time to time, to comb them. Such as have been sufficiently acted upon may then be set aside. They are lastly freed from the dust by being subjected to a grated cylinder in a state of rotation, and then combed by hand.

FUSEL OIL. During the rectification of corn or grape spirits there is always separated a fiery fœtid oil of nauseous odour and taste. It is this substance which is the cause of the unpleasant effects which are produced upon most persons by even a small quantity of insufficiently rectified whiskey or brandy. Any spirit which produces milkiness on the addition of four or five times its volume of water may be suspected to contain it. By repeated rectification every trace may be removed.

Fusel oil invariably consists of one or more homologues of the vinic alcohol ($C^4H^6O^2$), mixed with variable quantities of the latter substance and water. The nature of fusel oil varies much with the source from whence it is obtained. That which is ordinarily sold in this country for the purpose of yielding pear essence consists mainly of the amylic alcohol ($C^{10}H^{12}O^2$), mixed with from one-fourth to one-fifth of spirit of wine.

The progress of organic chemistry has been greatly assisted by the researches which have been made upon fusel oil, almost all the amylic compounds hitherto obtained having been directly or indirectly obtained from it.

To obtain fusel oil in a state of purity it is necessary, in the first place, to rectify it fractionally. By this means it will be found that much alcohol can be removed at once. If a great quantity of water and very little vinic alcohol be present, the simplest mode of purification is to shake it with water, by which means common alcohol is removed in solution, while the amylic alcohol, owing to its comparative insolubility, may be easily separated by the tap-funnel. After drying over chloride of calcium, it is to be again rectified once or twice, only that portion distilling at about 269·6° Fahr. (132° Cent.) being received. The product of this operation is pure amylic alcohol, from which an immense number of derivations of the amylic series can be obtained. By treatment with sulphuric acid and bichromate of potash it is converted into valerianic acid. In this manner all the valerianic acid, now so much employed in medicine is prepared. By distilling amylic alcohol with sulphuric acid and acetate of potash, we obtain the acetate of amyle, commercially known as jargonelle pear essence.

The foreign fusel oils obtained from the grape marc contain several homologues

higher and lower in the series than the amylic alcohol. In fact, it would appear that during the fermentation of grapes there are formed, not only alcohols, but ethers and acids.

M. Chancel, by repeatedly rectifying the dehydrated and more volatile portions of the residues of the distillation of grape marc alcohol, succeeded in isolating a fluid boiling at 205° Fahr. This proved to be pure propionic alcohol. M. Wurtz has also been able to obtain the butylic alcohol by rectifying certain specimens of potato oil.

All fusel oils are not so complex. The author of this article has repeatedly examined specimens of English and Scotch fusel oil, which did not contain anything save the ethylic and amylic alcohols, accompanied by small portions of the acids, which are procured by their oxidation. M. Chancel has given the following equations, which explain the manner in which saccharine matters break up into homologous alcohols under the influence of ferments. I have reduced the unitary notation employed by him into the ordinary formulæ used in this country, in order to render the relations as clear as possible to the reader.

$$\underbrace{2C^{12}H^{12}O^{12}}_{\text{Glucose}} = 8CO^2 + \underbrace{4C^4H^6O^2}_{\text{Alcohol.}}.$$

$$2C^{12}H^{12}O^{12} = 8CO^2 + C^4H^6O^2 + \underbrace{2C^6H^8O^2}_{\text{Propionic alcohol.}} + 2HO.$$

$$2C^{12}H^{12}O^{12} = 8CO^2 + \underbrace{2C^8H^{10}O^2}_{\text{Butylic alcohol.}} + 4HO.$$

$$2C^{12}H^{12}O^{12} = 8CO^2 + C^6H^8O^2 + \underbrace{C^{10}H^{12}O^2}_{\text{Amylic alcohol.}} + 4HO.$$

M. Chancel appears to consider the last equation as indicating the necessity of propionic alcohol being always formed wherever amylic alcohol is generated; but this is not in accordance with the results of those chemists who have examined crude amylic alcohol repeatedly for propionic alcohol, but without finding any. The formation of these interesting homologues appears therefore to depend upon special circumstances connected with the fermentation.

The caproic alcohol is also contained in certain varieties of fusel oil.

In order to assist those who may wish to examine the fluid alluded to, the following table of the physical properties of the alcohols up as high as the caproic has been inserted:—

Table of the Physical Properties of some Homologous Alcohols found in Fusel Oils.

Name.	Observers.	Formula.	Boiling Point.	Specific Gravity.	Vapour Density.	
					Experiments.	Calculation.
Methylic	Dumas and Peligot	$C^2H^4O^2$	152°	0·7980 at 68°	1·120	1·1072
Ethylic -	Gay-Lussac -	$C^4H^6O^2$	172°	0·7938 at 60°	1·613	1·3916
Propionic -	Chancel - -	$C^6H^8O^2$	205°	- - -	2·020	2·0760
Butylic -	Wurtz - - -	$C^8H^{10}O^2$	233°	- - -	- -	2·5304
Amylic -	Balard and Dumas	$C^{10}H^{12}O^2$	270°	0·8184 at 59°	3·147	3·0448
Caproic -	Faget - - -	$C^{12}H^{14}O^2$	304°	0·8330 at 32°	3·530	3·5292

Fusel oil, in addition to these homologous alcohols, contains several fatty acids. The following list contains the acids found in fusel oil, with the name of the observer.

Name of Acid.	Formula.	Observer.
Formic - - - -	$C^2H^2O^4$	Wetherill
Acetic - - - -	$C^4H^4O^4$	Kent
Valerianic - - -	$C^{10}H^{10}O^4$	Kent
Caproic - - - -	$C^{12}H^{12}O^4$	Wetherill
Œnanthylic - - -	$C^{14}H^{14}O^4$	Mulder, Wetherill
Caprylic - - -	$C^{16}H^{16}O^4$	Wetherill
Capric - - - -	$C^{20}H^{20}O^4$	Rowney
Margaric - - -	$C^{34}H^{34}O^4$	Kolbe

Fusel oil has been patented as a solvent for quinine, but its odour, and more especially that produced by its oxidation, so persistently adheres to anything with which it has been in contact, that great care is requisite in the purification. It is remarkable that at the first instant of smelling most specimens of fusel oil, the odour is not unpleasant, but in a very few seconds it becomes exceedingly repulsive, and provokes coughing.—C. G. W.

FUSES. See SAFETY FUSES.

FUSIBILITY. That property by which solids assume the fluid state under the influence of heat. With a few exceptions, such as carbon and some organic bodies, all substances appear capable of assuming the fluid state. Although we do not appear to have actually fused charcoal by means of the voltaic battery, the diamond has been fused and converted from a crystalline gem into a mass of opaque coke.

Thenard has thus grouped the metals: —

1. Fusible below a red heat: — *Mercury, potassium, sodium, tin, bismuth, lead, tellurium, arsenic, zinc, antimony, cadmium.*

2. Infusible below a red heat: — *Silver, copper, gold, cobalt, iron, manganese, nickel, palladium, molybdenum, uranium, tungsten, chromium, titanium, cerium, osmium, iridium, rhodium, platinum, columbium.*

Pouillet has, in his admirable treatise on heat, given the following table of the fusing points of various substances: —

Names.	Centigrade.	Names.	Centigrade.
Mercury	—39	Bismuth	202
Oil of turpentine	—10	Lead	320
Ice	0	Zinc	360
Tallow	33 to 38	Antimony	432
Acetic acid	45	Bronze	900
Spermaceti	49	Silver, very pure	1000
Stearine	49 to 43	Standard gold	1180
Margaric acid	55 to 60	Very fine gold	1250
Unbleached wax	61	White cast iron, very fusible	1050
White wax	68	White cast iron, second fusion	1200
Stearic acid	70	Grey cast iron, very fusible	1100
Phosphorus	43	Grey cast iron, second fusion	1200
Potassium	58	Manganesed cast iron	1250
Sodium	90	The more fusible steels	1300
Iodine	107	The less fusible steels	1400
Sulphur	114	Soft iron (French)	1500
Tin	230	English hammered iron	1600

FUSIBLE METAL. See ALLOY.

This alloy owes its peculiar property of melting at a comparatively low temperature to the presence of bismuth.

8	parts of bismuth,	5	of lead,	3	of tin	- melt at 212° F.
2	do.	1	do.	1	do.	- do. 201° F.
5	do.	3	do.	2	do.	- do. 199° F.
8	do.	5	do.	4	of tin, and 1 of type metal	

is an alloy much used on the continent for producing casts of metals by the *clichée* process. A mixture of bismuth, lead, tin, and antimony is used in this country for obtaining copies from wood blocks. Mr. Cowper used 1 of bismuth and 2 of tin to make the alloy most suitable for rose engine and eccentric turned pattern, to be printed from after the manner of letter press.

The soft solders used by pewterers consist of tin, lead, and bismuth in various proportions; indeed, bismuth enters to a greater or a less extent into all the soft solders.

Fusible metal has also been employed as a sort of safety valve for steam boilers. By adjusting the proportions of the above named metals, an alloy can be made which will melt at any required temperature; therefore, when the boiler rose to this temperature, the metal plug gave way and the steam escaped.

FUSTIAN, is a species of coarse thick tweeled cotton, and is generally dyed of an olive, leaden, or other dark colour. Besides the common fustian, which is known by the name of pillow (probably pilaw), the cotton stuffs called corduroy, velveret, velveteen, thickset, used for men's wearing apparel, belong to the same fabric. The commonest kind is merely a tweel of four, or sometimes five leaves, of a very close stout texture, and very narrow, seldom exceeding 17 or 18 inches in breadth. It is cut from the loom in half pieces, or ends as they are usually termed, about 35 yards

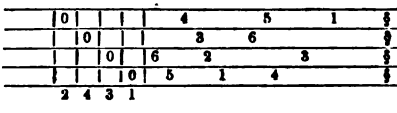
long, and after undergoing the subsequent operations of dyeing, dressing, and folding, is ready for the market.

The draught and cording of common fustian is very simple, being generally a regular or unbroken tweel of four or five leaves. Below are examples of a few different kinds, selected from those most general in Lancashire.

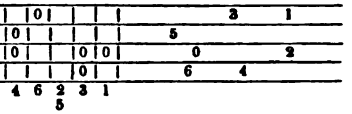
The number of leaves of heddles are represented by the lines across the paper, and the *cording* by the ciphers in the little squares, those which raise every leaf being distinguished by these marks, and those which sink them left blank, as more particularly explained in the article TEXTILE FABRIC.

When the material is silk, it is called velvet, when cotton, velveteen. A common tweeled cloth, when composed of silk is called satin; when of cotton, fustian or jean; of woollen, plaiding, serge, or kerseymere.

No. 1.—Pillow Fustian.

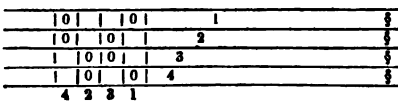


No. 2.—Plain Velveret.

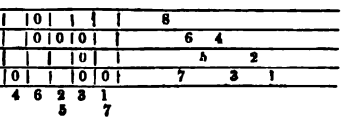


Of the above, each contains four leaves of heddles or healds: that represented by No. 1 is wrought by four treddles, and that which is distinguished by No. 2, by five; the succession of inserting the threads of warp into the heddles will be discovered by the figures between the lines, and the order in which the treddles are to be successively pressed down by the figures below.

No. 3.—Double Jean.

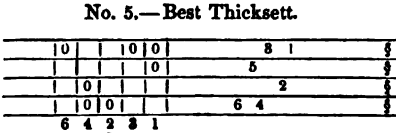


No. 4.—Plain Thicksett.

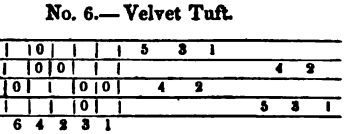


These, like the former, are wrought with leaves. No. 3 requires four, and No. 4 five treddles. The succession of inserting the threads of warp, and of working the treddles, are marked by the respective numbers between and under the lines, as in the former example. Both are fabrics of cloth in very general use and estimation as low priced articles.

No. 5.—Best Thicksett.

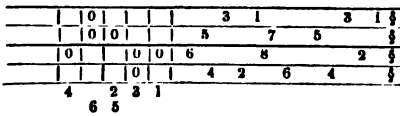


No. 6.—Velvet Tuft.

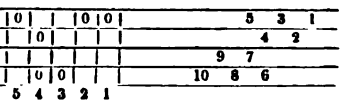


These are further specimens of what may be, and is, executed with four leaves, and in both examples five treddles are used. With two other specimens we shall conclude our examples of this description of work, and shall then add a very few specimens of the more extensive kinds.

No. 7.—Cord and Velveret.

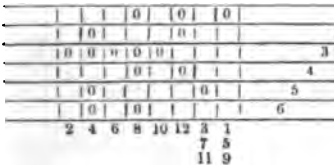


No. 8.—Thicksett Cord.

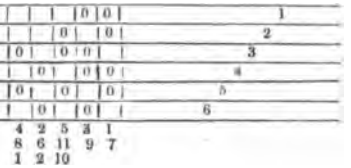


In these the succession of drawing and working are marked like the former. The next are examples of patterns wrought with six leaves. No. 9 has eight, and No. 10 five heddles.

No. 9.— Double Corduroy.

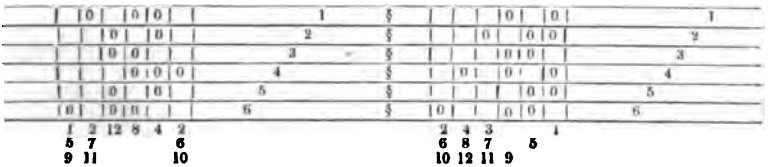


No. 10.— Genoa Thicksett.

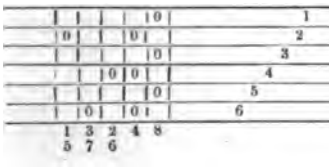


In both these the warp is inserted into the heddles the same way. The difference is entirely in the application of the cords, and in the succession of pressing down the treddles. We now give four specimens of the flushed and cut work, known by the name of velveteen. They are also upon six leaves, and the difference is solely in the cording and in the treading.

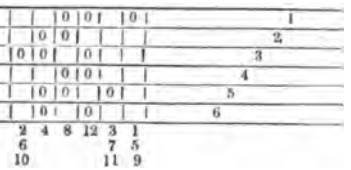
No. 11. Queen's Velveteens. No. 12.



No. 13.— Plain Velveteen.

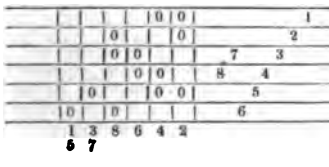


No. 14.— Genoa Velveteen.

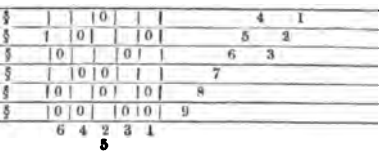


The additional varieties of figure which might be given are almost endless, but the limits of this article will not admit a further detail. Those already given are the articles in most general use. The varieties of fancy may be indulged to great extent, but it is universally found, that the most simple patterns in every department of ornamental weaving, are those which attract attention and command purchasers. We shall therefore only add an example of king's cord, or corduroy, and of Dutch cord, with one of Genoa and one of common velvet, to show the peculiarities.

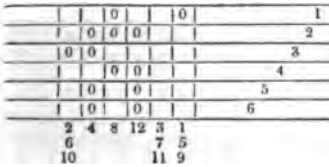
No. 15.— King's Cord.



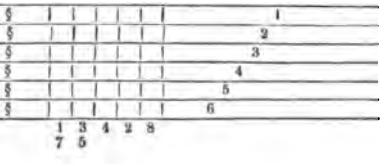
No. 16.— Dutch Cord.



No. 17.— Genoa Velvet.—



No. 18.— Plain Velvet.



After the fustian cloth is taken from the loom-beam, it is carried to the cutter, who rips up the surface-threads of weft, and produces thereby a hairy-looking stuff.

Preparatory to its being cut, the cloth is spread evenly upon a table about six feet long, upon each end of which a roller mounted with a ratchet-wheel is fixed ; the one to give off, and the other to wind up the piece, in the above six-feet lengths.

The knife is a steel rod about two feet long, and three-eighths of an inch square, having a square handle at the one end; the other end is tapered away to a blade, as thin as paper. To prevent this point from turning downwards and injuring the cloth, its under side is covered by a guide which serves to stiffen it, as well as to prevent its lower edge from cutting the fustian.

The operative (male or female) grasps the handle in the right hand, and insinuating the projecting point of the guide under the weft, pushes the knife smartly forward though the whole length of six feet, with a certain dexterous movement of the shoulder and right side, balancing the body meanwhile, like a fencer, upon the left foot. This process is repeated upon every adhesive line of the weft.

The next process to which fustians are exposed is steeping in hot water, to take out the dressing paste. They are then dried, reeled, and brushed by a machine, &c. From twenty to thirty pieces, each eighty yards long, may be brushed in an hour. The breadth of the cloth is twenty inches. The maceration is performed by immersing the bundled pieces in tanks of water, heated by waste steam; and the washing by means of a reel or winch, kept revolving rapidly under the action of a stream of cold water, for an hour or longer.

After being thus ripped up, it is taken to the brushing or teazling machine, to make it shaggy.

This consists of a series of wooden rollers, turning freely upon iron axles, and covered with tin-plate, rough with the burs of punched holes ; and blocks of wood, whose concave under surfaces are covered with card-cloth or card-brushes, and which are made to traverse backwards and forwards in the direction of the axes of the revolving rollers, during the passage of the cloth over them.

After they are brushed in the machine, the goods are singed by passing their cut surface over a cylinder of iron, laid in a horizontal direction, and kept red hot by a flue. They are now brushed again by the machine, and once more passed over the singeing surface. The brushing and singeing are repeated a third or even occasionally a fourth time, till the cord acquires a smooth polished appearance.

The goods are next steeped, washed, and bleached by immersion in solution of chloride of lime. They are then dyed by appropriate chemical means. After which they are padded (imbued by the padding machine of the calico printers) with a solusition of glue, and passed over steam cylinders to stiffen them.

Smooth fustians, when cropped or shorn before dyeing, are called moleskins; but when shorn after being dyed, are called beverteen; they are both tweeled fabrics. Cantoon is a fustian with a fine cord visible upon the one side, and a satiny surface of yarns running at right angles to the cords upon the other side. The satiny side is sometimes smoothed by singeing. The stuff is strong, and has a very fine aspect.

FUSTIC, or YELLOW WOOD. (*Bois jaune*, Fr.; *Gelbholz*, Germ.) The *old* fustic of the English dyer. It is the wood of the *Morus tinctoria*. It is light, not hard, and pale yellow with orange veins; it contains two colouring matters, one resinous, and another soluble in water. Chevreul has given the name of *morin* to the colouring matter obtained from fustic. It is procured by boiling ground fustic in distilled water, passing the decoction rapidly through a filter, and allowing the liquid to stand for several days, when the colouring matter (*morin*) is precipitated.

The decoctions of fustic in water are brightened by the addition of a little glue, and still more so by curdled milk. This wood is rich in colour, and imparts permanent dyes to woollen stuffs, when aided by proper mordants. It unites well with the blue of the indigo vat, and Saxon blue, in producing green of various shades. Alum, tartar, and solution of tin, render its colour more vivid; sea salt and sulphate of iron deepen its hue. From 5 to 6 parts of old fustic are sufficient to give a lemon colour to 16 parts of cloth. This wood is often employed with sulphate of iron in producing olive and brownish tints, which agree well with its dull yellow. For the same reason it is much used for dark greens.

The bichromates of potash and of lead, have nearly superseded the use of fustic, but still, it is employed for producing some green in cotton yarn, and in light cotton fabrics, as gauzes and muslins.

FUSTIC, *Young*. (*Fustet*, Fr.) The wood of the *Rhus cotinus*, a shrub which grows principally in the south of France and in Italy, called also *Venetian sumach*. This wood contains a large quantity of yellow colouring matter, named *fusteric*. This colouring matter has a strong attraction for oxygen, which affects its use as a dye, rendering it very fugitive. It is rarely used alone, but as an assistant to strike some particular tint.

G.

GABRONITE, is a yellowish stony substance, of a greasy lustre and sp. gr. = 2·74; affording no water by calcination; fusible at the blowpipe into an opaque glass; soluble in muriatic acid; solution affords hardly any precipitate by oxalate of ammonia. This mineral is distinguished by the large quantity of soda which it contains; its constituents being, silica, 54; alumina, 24; soda, 17·25; magnesia, 1·5; oxide of iron, 1·25; water 2. It is most probably a variety of Scapolite.

GAD. A miner's tool; a pointed wedge having its sides of a parabolic figure.

GADIDÆ. The cod-fish family. Beyond the value of the cod-fish as an article of food, the cod liver oil is now an important manufacture. See COD.

GADOLINITE; called also Yttrite and Ytterbyte; is a mineral of a black, brownish, or yellowish colour, granular, or compactly vitreous, and conchoidal fracture; of sp. gr. 4·0 to 4·5, readily scratching glass; at the blowpipe it forms an opaque glass, sometimes with intumescence, but does not fuse into a bead. It affords, with acids, a solution that lets fall, with caustic soda, a precipitate partly resoluble in carbonate of ammonia. It is remarkable for containing from 45 to 55 per cent. of the earth yttria: its remaining constituents being silica, 25·8; oxide of cerium, 17·92; oxide of iron, 11·43. This mineral is very rare, is found in the neighbourhood of Fahlun and Ytterby, in Sweden; also at Disko, in Greenland; in trap, near Galway; in granite, in Ceylon; and in the south of Norway. Its peculiar constituent was discovered by Professor Gadolin, after whom it is named.

GALACTOMETER, or LACTOMETER, is an instrument to ascertain the quality of milk; an article often sophisticated in various ways. Fresh milk, rich in cream, has a less specific gravity than the same milk after it has been skimmed; and milk diluted with water becomes proportionally lighter. Hence, when our purpose is to determine the quantity of cream, the galactometer may consist merely of a long graduated glass tube standing upright upon a sole. Having filled 100 measures with the recent milk, we shall see, by the measures of cream thrown up, its value in this respect. A delicate long-ranged glass hydrometer, graduated from 1·000 up to 1 060 affords the most convenient means of detecting the degree of watery dilution, provided the absence of thickening materials has been previously ascertained by filtration. Good fresh milk indicates from 1·030 to 1·032; when the cream is removed, 1·035 to 1·037. When its density is less than 1·028, we may infer it has been thinned with water.

GALBANUM is a gum-resin, which occurs sometimes in yellow shining tears, easily agglutinated; of a strong durable smell; an acrid and bitter taste: at other times in lumps. It exudes either spontaneously or from incisions made into the stem of the *bubon galbanum*, a plant of the family of *umbelliferæ*, which grows in Africa, particularly in Ethiopia. It contains 67 of resin; 19·3 of gum; 6·4 of volatile oil and water; 7·5 of woody fibres and other impurities; with traces of acid malate of lime.

GALENA (*Plomb sulfure*, Fr.; *Bleiglanz*, Germ.) is a sulphide (sulphuret) of lead. It is of a lead-grey colour, crystallises in the cubical system, and is susceptible of cleavages parallel to the faces of the cube; sp. gr. 7·7592; cannot be cut; fusible at the blowpipe with exhalation of sulphureous vapours; is easily reduced to metallic lead. Nitric acid first dissolves it, and then throws down sulphate of lead in a white precipitate; the solution affording with plates of zinc brilliant laminæ of lead (arbor Saturni). It consists of sulphur 13; lead 85; with a little iron, and generally a small quantity of silver. This is the richest ore of lead, and it occurs in almost every geological formation, in veins, in masses, or in beds. Galena in powder, called Alquifoux, is employed as a glaze for coarse stoneware. See LEAD.

GALIPOT, is a name of a white semi-solid viscid resin, found on fir-trees; or an inferior sort of turpentine, poor in oil.

GALL OF ANIMALS. See OX GALL.

GALL OF GLASS, called also SANDIVER, is the neutral salt skimmed off the surface of melted crown glass; which, if allowed to remain too long, is apt to be reabsorbed in part, and to injure the quality of the *metal*, as the workmen call it. See GLASS.

GALLATES; salts consisting of gallic acid combined with bases; the most important being that with oxide of iron, constituting a principal part of the black dye.

GALLERY, *in mining*, in some districts, an underground horizontal excavation.

GALLIARD, a north of England term for a hard, smooth, flinty grit.

GALLIC ACID is the peculiar acid extracted from gall-nuts. See GALL-NUTS.

GALLIPOLI OIL is a coarse olive oil, containing more or less mucilage, imported

from a seaport so named, of the province of Otranto, in the kingdom of Naples. See OLIVE OIL.

GALL-NUTS, or GALLS (*Noix de Galle*, Fr.; *Galläpfel*, Germ.), are excrescences found upon the leaves and leaf-stalks of a species of oak, called *Quercus infectoria*, which grows in the Levant. They are produced in consequence of the puncture of the female of the gall wasp (*Cynips folii quercus*), made in order to deposit her eggs; round which the juice of the tree exudes, and dries in concentric portions. When the insect gets fully formed, it eats through the nut and flies off.

The Levant galls are of two different appearances and qualities; the first are heavy, compact, imperforated, the insect not having been sufficiently advanced to eat its way through the shell; prickly on the surface; of a blackish or bluish green hue; about the size of a musket ball. These are called *black*, blue, or Aleppo galls. The second are light, spongy, pierced with one or more holes; smooth upon the surface, of a pale greyish or reddish yellow colour, generally larger than the first, and are called *white* galls; but they are inferior to the former, and great care should be taken in the purchase of the best quality, for these are often dyed by dishonest traders to imitate the best blue Aleppo galls, but the fraud may be detected by the small hole made by the insect in the white galls, so that if the blue galls have holes, we may be sure they are not genuine.

Besides the galls of the Levant, others come from Dalmatia, Illyria, Calabria, &c.; but they are of inferior quality, being found upon the *Quercus cerris*; they are smaller, of a brownish colour, and of inferior value. The further south the galls are grown, they are reckoned the better.

Galls consist principally of three substances; tannin, or tannic acid; yellow extractive; and gallic acid. Their decoction has a very astringent and unpleasant bitter taste. The following are their habitudes with various reagents: —

Litmus paper is powerfully reddened.

Stannous chloride (*protomuriate of tin*) produces an Isabel yellow precipitate.

Alum; a yellowish grey precipitate.

Acetate of lead; a thick yellowish white precipitate.

Acetate of copper; a chocolate brown precipitate.

Ferric sulphate (red sulphate of iron); a blue precipitate.

Sulphuric acid; a dirty yellowish precipitate.

Acetic acid brightens the muddy decoction.

The galls of the *Quercus cerris* and common oak (*Galles à l'épine*, Fr.; *Knoppern*, Germ.) are of a dark-brown colour, prickly on the surface, and irregular in shape and size. They are used chiefly for tanning in Hungary, Dalmatia, and the southern provinces of the Austrian states, where they abound.

Tannin or tannic acid is prepared as follows: Into a long narrow glass adopter tube, shut at its lower orifice with a cotton wick, a quantity of pounded galls are put, and slightly pressed down. The tapering end of the tube being inserted into a matrass or bottle, the vacant upper half of the tube is filled with sulphuric ether, and then closed with a ground-glass stopper. Next day there will be found in the bottle a liquid in two distinct strata; of which the more limpid occupies the upper part, and the other, of a sprupy consistence and amber colour, the lower. More ether must be filtered through the galls, till the thicker liquor ceases to augment. Both are now poured into a funnel, closed with the finger, and after the dense liquor is settled at the bottom, it is steadily run off into a capsule. This, after being washed repeatedly with ether, is to be transferred into a stove chamber, or placed under the receiver of an air pump to be evaporated. The residuary matter swells up in a spongy crystalline form of considerable brilliancy, sometimes colourless, but more frequently of a faintly yellowish hue.

This is pure tannin, which exists in galls to the amount of from 40 to 45 per cent. It is indispensable that the ether employed in the preceding process be previously agitated with water, or that it contain some water, because by using anhydrous ether, not a particle of tannin will be obtained.

Tannic acid is a white or yellowish solid, inodorous, extremely astringent, very soluble in water and alcohol, much less so in sulphuric ether, and uncrystallisable. Its watery solution, out of contact of air, undergoes no change; but if, in a very dilute state, it be left exposed to the atmosphere, it loses gradually its transparency, and lets fall a slightly greyish crystalline matter, consisting almost entirely of gallic acid. For procuring this acid in a perfectly pure state, it is merely necessary to treat that solution thus changed with animal charcoal, and to filter it in a boiling state, through paper previously washed with dilute muriatic acid. The gallic acid will fall down in crystals as the liquid cools.

If the preceding experiment be made in a graduated glass tube containing oxygen over mercury, this gas will be absorbed, and a corresponding volume of carbonic acid

gas will be disengaged. In this case the liquor will appear in the course of a few weeks as if traversed with numerous crystalline colourless needles of gallic acid.

Tannin or tannic acid consists of carbon, 51·56; hydrogen, 4·20; oxygen, 44·24.

From the above facts it is obvious that gallic acid does not exist ready formed in gall-nuts, but that it is produced by the reaction of atmospheric oxygen upon the tannin of these concretions.

Gallic acid is a solid, feebly acidulous and styptic to the taste, inodorous, crystallising in silky needles of the greatest whiteness; soluble in about 100 times its weight of cold, and in a much smaller quantity of boiling water; more soluble in alcohol than in water, but little so in sulphuric ether.

Gallic acid does not decompose the salts of protoxide of iron, but it forms, with the sulphate of the peroxide, a dark blue precipitate, much less insoluble than the tannate of iron.

Galls *imported* in 1857:—

	Cwts.	Computed real value.
From France	437	£2,092
„ Greece	333	1,594
„ Turkey Proper	2,113	10,116
„ Syria and Palestine	3,135	15,009
„ United States	382	1,829
„ British East Indies	936	4,481
„ Other parts	744	3,562
	8,080	£38,683

GALVANISED IRON. This is the name, improperly given, first in France, and subsequently adopted in this country, to iron coated with zinc by a peculiar patent process.

In 1837 Mr. H. W. Crawfurd patented a process for zincing iron. In the "*Repertory of Patent Inventions*" his process is thus described:—Sheet iron, iron castings, and various other objects in iron are cleaned and scoured by immersion in a bath of water, acidulated with sulphuric acid, heated in a leaden vessel, or used cold in one of wood, just to remove the oxide. They are then thrown into cold water, and taken out one at a time to be scoured with sand and water with a piece of cork, or more usually with a piece of the husk of the cocoa nut, the ends of the fibres of which serve as a brush, and the plates are afterwards thrown into cold water.

Pure zinc covered with a thick layer of sal-ammoniac is then melted in a bath, and the iron, if in sheets, is dipped several sheets at a time in a cradle or grating. The sheets are slowly raised to allow the superfluous zinc to drain off, and are thrown whilst hot into cold water, on removal from which they only require to be wiped dry.

Thick pieces are heated before immersion in a reverberatory furnace, to avoid cooling the zinc. Chains are similarly treated, and on removal from the zinc require to be shaken until cold to avoid the links being soldered together. Nails and small articles are dipped in muriatic acid, and dried in a reverberatory furnace, and then thrown altogether in the zinc, covered with the sal-ammoniac, left for one minute, and taken out slowly with an iron skimmer; they come out in a mass soldered together, and for their separation are afterwards placed in a crucible and surrounded with charcoal powder, then heated to redness and shaken about until cold for their separation. Wire is reeled through the zinc, into which it is compelled to dip by a fork or other contrivance. It will be understood that the zinc is melted with a thick coat of sal-ammoniac to prevent the loss of zinc by oxidation.

Mr. Mallett coated iron with zinc by the following process:—

The plates are immersed in a cleansing bath of equal parts of sulphuric or muriatic acid and water, used warm; the works are then hammered and scrubbed with emery and sand to detach the scales, and to thoroughly clean them; they are then immersed in a "preparing bath" of equal parts of saturated solutions of muriate of zinc and sal-ammoniac, from which the works are transferred to a fluid metallic bath, consisting of 202 parts of mercury and 1292 parts of zinc, both by weight, to every ton weight of which alloy is added above one pound of either potassium or sodium, the latter being preferred. As soon as the cleaned iron-works have attained the melting heat of the triple alloy, they are removed, having become thoroughly coated with zinc. At the proper fusing temperature of this alloy, which is about 680° Fahr., it will dissolve a plate of wrought iron of an eighth of an inch thick in a few seconds.

Morewood and Rogers's galvanised tinned iron is prepared under several patents. Their process is as follows:—

The sheets are pickled, scoured, and cleaned just the same as for ordinary tinning.

A large wooden bath is then half filled with a dilute solution of muriate of tin, prepared by dissolving metallic tin in concentrated muriatic acid, which requires a period of two or three days. Two quarts of the saturated solution are added to 300 or 400 gallons of the water contained in the bath. Over the bottom of the bath is first spread a thin layer of finely granulated zinc, then a cleaned iron plate, and so on, a layer of granulated zinc and a cleaned iron plate alternately, until the bath is full; the zinc and iron together with the fluid constitute a weak galvanic battery, and the tin is deposited from the solution so as to coat the iron with a dull uniform layer of metallic tin in about two hours.

The tinned iron is then passed through a bath containing fluid zinc, covered with sal-ammoniac mixed with earthy matter, to lessen the volatilisation of the sal-ammoniac, which becomes as fluid as treacle. Two iron rollers immersed below the surface of the zinc, are fixed to the bath and are driven by machinery to carry the plates through the fluid metal at any velocity previously determined. The plates are received one by one from the tinning bath, drained for a short time, and passed at once, whilst still wet, by means of the rollers, through the bath as described. The plates take up a very regular and smooth layer of zinc, which, owing to the presence of the tin beneath, assumes its natural crystalline character, giving the plates an appearance resembling that known as the *moirée metallique*.—See *Hunt's Handbook to the Great Exhibition.*

It is stated that galvanised iron plates cut with shears so as to expose the central iron become zinced round the edges, and at the holes where the nails were driven. We are also informed that *ungalvanised iron* will, if moist when near galvanised plate, become zinced, and that telegraph wires, where cut through, become coated by the action of the rain-water on the galvanised portion of the surfaces.

It has been stated that the galvanised iron is not more durable than unprotected iron; that, indeed, where the zinc is by any accident removed the destruction is more rapid than ordinary. We have made especial inquiries, and find that in forges where there is any escape of sulphur vapour the galvanised iron does not stand well; but that under all ordinary circumstances it has the merit of great durability in addition to its other good qualities.

GALVANO-PLASTIC. The German name of Electro-metallurgy.

GAMBIR, or GAMBIER. The Malayan name of an extract obtained from the *Uncaria Gambier*. It is the *Terra Japonica* of tanners.

Two methods of obtaining gambir are described: one consists in boiling the leaves in water, and inspissating the decoction; the other, which yields the best gambir, consists in infusing the leaves in warm water, by which a fecula is obtained, which is inspissated by the heat of the sun and formed into cakes. The best gambir is made at Rhio, in the Isle of Brittany, in the Eastern Archipelago; and the next best is that of Lingin. It is principally imported from Singapore, and is used principally for tanning, under the name of *Terra Japonica*. The *Mimosa catechu* yields a different extract from the gambir, but catechu and gambir are often confounded.

The *imports* have been 1856, 8536 tons; 1857, 11,047 tons.

GAMBIR CATECHU. See CATECHU.

GAMBOGE. (*Gomme Gutte*, Fr.; *Gutti*, Germ.) Gamboge appears to have been first brought from China about 1603, and its oriental name was said to be *Ghittaiemon*.

It is generally supposed to be produced from the *Hebradendron cambogioides* of Graham, and the *Xanthochymus ovalifolius* of Roxburgh. In Ceylon the gamboge is obtained by wounding the bark of the tree in various places with a sharp stone, when the flowers begin to appear. Gamboge is imported from Siam, by way of Singapore and Penang. It is known in three forms. In rolls or solid cylinders; in pipes or hollow cylinders; in cakes or amorphous masses. Gamboge in small quantities is also obtained in Ceylon.

Gamboge consist of—

Resin	74·2
Soluble gum	21·8
Moisture	4·8
	100·8

Gamboge is employed as an artist's colour; it is used to colour varnishes and lacquers, and it is administered medicinally.

We *imported* in 1857, 248 cwts.

GAMMAM. A dye stuff, so called, from Tunis. Examples were sent to this country in 1851, but it does not appear to have been introduced since that time.

GANGUE. A word derived from the German *gang*, a vein or channel. It signifies the mineral substance which either encloses or usually accompanies any metallic

ore in the vein. Quartz, lamellar carbonate of lime, sulphate of baryta, sulphate and fluate of lime, generally form the gangues; but a great many other substances become such when they predominate in a vein. In mineral works the first thing is to break the mixed ore into small pieces, in order to separate the valuable from the useless parts, by processes called stamping, picking, sorting. See MINING.

GARANCIN. See MADDER.

GARANCEUX. See MADDER.

GARLIC. *Allium sativum.* This plant is well known, and is much used in flavouring sauces.

It is found by analysis to contain an acrid volatile oil, gum, woody fibre, albumen, water, with sulphur, starch, and saccharine matter. The *oil of garlic* is a sulphide of allyle, $AllS = C^6H^5S$.

GARNET. (*Grenat*, Fr.) Garnet is a silicate of some base, which may be lime, magnesia, oxide of iron, &c.

There are six sub-species of garnet, viz.:—

I. *Alumina-lime garnet*, consisting of the silicates of alumina and lime.

II. *Alumina-magnesia garnet*, consisting of the silicates of alumina and magnesia.

III. *Alumina-iron garnet*, consisting of the silicates of alumina and iron.

IV. *Alumina-manganese garnet*, consisting of the silicates of alumina and manganese.

V. *Iron-lime garnet*, consisting of the silicates of iron and lime.

VI. *Lime-chrome garnet*, consisting of the silicates of lime and oxide of chromium.

I. Lime-garnet, or grossular, is composed of silica, 40·1; alumina, 22·7; lime, 37·2 = 100·0. Colour, pale greenish, clear red, and reddish orange, cinnamon colour. Before the blowpipe, fuses to a slightly greenish glass or enamel; soluble, when powdered, in concentrated muriatic acid.

This section comprises cinnamon-stone or Essonite, grossular or Wiluite, Romanzovite, topazolite, and succinite.

II. Magnesia-garnet is of a deep coal-black colour, with a resinous lustre. The variety from Arendal is composed of silica, 42·45; alumina, 22·47; protoxide of iron, 9·29; protoxide of manganese, 6·27; magnesia, 13·43; lime, 6·53 = 100·44.—(*Wächtmeister.*) Before the blowpipe, easily fusible, forming with intumescence a dark greyish-green globule, which is non-magnetic.

III. Iron-garnet comprises the almandine or precious garnet, allochroite, and common garnet. It is composed of silica, 36·3; alumina, 20·5; protoxide of iron, 43·2 = 100·0. Before the blowpipe, fuses rather easily with an iron reaction.

IV. Manganese-garnet, or spessartine, is of a brownish-red colour, and is composed of silica, 35·83; alumina, 18·06; protoxide of iron, 14·93; protoxide of manganese, 30·96 = 99·78. (Analysis of M. garnet from Haddam, U. S., by *Seybert.*) Before the blowpipe, gives a manganese reaction.

V. Iron-lime garnet includes aplome, colophonite, melanite, and pyreneite. These vary in colour from dark red, brownish-black, to black, and possess a shining lustre, which is sometimes resinous, as in colophonite.

Analysis of the aplome of Altenau:—Silica, 35·64; lime, 29·22; protoxide of iron, 30·00; protoxide of manganese, 3·01; potash, 2·35 = 100·22.—*Wächtmeister.*

VI. Lime-chrome garnet, or ouvarovite, is of an emerald-green colour. Sp. gr., 3·418. Before the blowpipe it is infusible alone, but with borax affords a chrome-green glass. It occurs at Bissersk, in Russia.

Analysis by *Erdmann*:—Silica, 36·93; alumina, 5·68; peroxide of iron, 1·96; oxide of chrome, 21·84; magnesia, 1·54; carbonate of lime, 31·66; oxide of copper, a trace = 99·58.

The garnet varies greatly in transparency, fracture, and colour; but when the colours are rich, and the stone is free from flaws, it constitutes a valuable gem, which may be distinguished by the following properties:—

The colour should be blood or cherry-red; on the one hand often mixed more or less with blue, so as to present various shades of crimson, purple, and reddish violet, and on the other hand, with yellow, so as to form orange-red and hyacinth brown.

The stones vary in size from the smallest pieces that can be worked to the size of a nut. When above that size they are scarcely ever free from flaws, or sufficiently transparent for the purposes of the jeweller.

The garnets of commerce are procured from Bohemia, Ceylon, Pegu, and the Brazils. By jewellers they are classed as Syrian, Bohemian, or Cingalese, rather from their relative value and fineness, than with any reference to the country from which they are supposed to have been brought.

Those most esteemed are called Syrian garnets, not because they come from Syria, but after Syrian, the capital of Pegu, which city was formerly the chief mart for the finest garnets. The colour of the Syrian garnet is violet-purple, which, in some rare

instances, vies with that of the finest oriental amethyst; but it may be distinguished from the latter by acquiring an orange tint by candle-light. The Syrian garnet may be also distinguished from all the other varieties of garnet in preserving its colour (even when of considerable thickness and unassisted by foil), unmixed with the black tint which usually obscures this gem. The Bohemian garnet is generally of a dull poppy-red colour, with a very perceptible hyacinth-orange tint when held between the eye and the light. When the colour is a full crimson it is called pyrope, or fire garnet, a stone of considerable value when perfect and of large size.

The best manner of cutting the pyrope is *en cabochon*, with one or two rows of small facets round the girdle of the stone. The colour appears more or less black when the stone is cut in steps, but when cut *en cabochon*, the points on which the light falls display a brilliant fire-red.

Garnet is easily worked, and when facet-cut is nearly always (on account of the depth of its colour) formed into thin tables, which are sometimes concave or hollowed out on the under side. Cut stones of this latter description, when skilfully set, with a bright silver foil, have often been sold as rubies.

The garnet may be distinguished from corundum or spinel by its duller colour. Coarse garnets reduced to a fine powder are sometimes used as a substitute for emery in polishing metals.

Bohemian garnet. See PYROPE.—H. W. B.

GAS. (*Gas*, Fr.; *Gaz*, Germ.) The generic name of all such elastic fluids as are aeriform under a considerable pressure, at the zero of Fahrenheit. Oxygen, hydrogen, and nitrogen, are permanent gases; many of the other vaporiform bodies have been condensed by the joint power of cold and mechanical force. See *Ure's Dictionary of Chemistry.*

GAS-HOLDER. A vessel for containing and preserving gas, of which various forms are described by chemical writers.

GAS, LAUGHING. *Protoxide of Nitrogen*; also *Protoxide of Azote*, and *Nitrous Oxide*. This gas is always prepared from the nitrate of ammonia; it was first described by Priestley, in 1776, and carefully studied by Davy. This gas is chiefly remarkable for the peculiar intoxication which it produces when breathed. It is not to be used without much caution. If it is not very pure, serious consequences may ensue; and even when absolutely pure, the editor has seen the nitrous oxide produce very distressing effects. It is not used in the arts. See *Ure's Dictionary of Chemistry.*

GASOMETER, means properly a measurer of gas, though it is employed often to denote a recipient of gas of any kind. See COAL-GAS.

GAS-PIPES. When the illumination by gas was first introduced in the large way by Aaron Manby, Esq., then of the Horsley Iron Works, the old musket barrels, laid by in quiet retirement from the fatigues of the last war, were employed for the conveyance of gas; and by a curious coincidence, various iron foundries desisted in a great measure from the manufacture of iron ordnance, and took up the peaceful employment of casting pipes for gas and water.

The breach-ends of the musket-barrels were broached and tapped, and the muzzles were screwed externally, to connect the two without detached sockets. From the rapid increase of gas illumination, the old gun-barrels soon became scarce, and new tubes with detached sockets, made by the old barrel-forgers, were first resorted to. This led to a series of valuable contrivances for the manufacture of the wrought iron tubes, commencing with the Russell's patent, in 1824, under which the tubes were first bent up by hand hammers and swages, to bring the edges near together; and they were welded between semi-circular swages, fixed respectively in the anvil, and the face of a small tilt-hammer worked by machinery, by a series of blows along the tube either with or without a mandrel. The tube was completed on being passed between rollers with half-round grooves, which forced it over a conical or egg-shaped piece at the end of a long bar to perfect the interior surface.

Various steps of improvements have been since made; for instance, the skelps were bent at two squeezes, first to the semi-cylindrical, and then to the tubular form preparatory to welding, between a swage tool five feet long worked by machinery. The whole process was afterwards carried on by rollers, but abandoned on account of the unequal velocity at which the greatest and least diameters of the rollers travelled.

In the present method of manufacturing the patent welded tube, the end of the skelp is bent to the circular form, its entire length is raised to the welding heat in an appropriate furnace, and as it leaves the furnace almost at the point of fusion it is dragged by the chain of a draw-bench, after the manner of wire, through a pair of tongs with two bell-mouthed jaws, these are opened at the moment of introducing the end of the skelp, which is welded without the agency of a mandrel.

By this ingenious arrangement wrought-iron tubes may be made from the diameter of six inches internally, and about one-eighth to three-eighths of an inch thick, to as

small as one quarter inch diameter and one-tenth bore ; and so admirably is the joining effected in those of the best description, that they will withstand the greatest pressures of gas, steam, or water to which they have been subjected, and they admit of being bent both in the heated and cold state almost with impunity. Sometimes the tubes are made one upon the other when greater thickness is required, but these stout pipes and those larger than three inches are comparatively but little used. —(*Holtzapffel.*)

GASSING, in order to remove the hairy filaments from net-lace and other woven fabrics, they are passed over a large number of minute jets of gas, and between rollers.

GAULT, a local term in some parts of England for clay, has been adopted into geological nomenclature to denote the argillaceous strata which separate the upper and lower greensands. It is a dark blue or grey clay, used for making bricks and tiles; it affords a poor agricultural soil, which is generally converted into pasture.—H. W. B.

GAULTHERIA OIL. WINTERGREEN OIL, which see.

GAULTHERINE. When the powdered bark of *betula lenta* is exhausted with cold alcohol of 95° it can afford no more oil. The fluid which contains the gaultherine has a slightly bitterish taste, and by evaporation it forms a dry gummy mass, which at a high heat leaves a coally residual. Oil of vitriol dissolves the *gaultherine* with a red colour and the flavour of the oil.

GAUZE WIRE CLOTH is a textile fabric, either plain or tweeled, made of brass, iron, or copper wire, of very various degrees of fineness and openness of textures. Its chief uses are for sieves and safety lamps.

GAY-LUSSITE, is a white mineral of vitreous fracture, which crystallises in oblique rhomboidal prisms; specific gravity from 1·93 to 1·95 ; scratches gypsum, but is scratched by calcspar ; affords water by calcination ; it consists of carbonic acid, 28·66 ; soda, 20·44 ; lime, 17·70 ; water, 32·30 ; clay, 1·00. It is, in fact, by my analysis, a hydrated soda-carbonate of lime in atomic proportions. This mineral occurs abundantly in insulated crystals, disseminated through the bed of clay which covers the *wrao*, or native sesquicarbonate of soda, at Lagunilla in Columbia.

GELATINE (Eng. and Fr.; *Gallert, Leim*, Germ.) is an animal product which is never found in the humours, but it may be obtained by boiling with water the soft and solid parts; as the muscles, the skin, the cartilages, bones, ligaments, tendons, and membranes. Isinglass consists of from 86 to 93 per cent. of gelatine. This substance is very soluble in boiling water; the solution forming a tremulous mass of jelly when it cools. Cold water has little action upon gelatine. Alcohol and tannin precipitate gelatine from its solution; the former by abstracting the water, the latter by combining with the substance itself into an insoluble compound, of the nature of leather. No other acid, except the tannic, and no alkali, possesses the property of precipitating gelatine. But chlorine and certain salts render its solution more or less turbid ; as the nitrate and bi-chloride of mercury, the proto-chloride of tin, and a few others. Sulphuric acid converts a solution of gelatine at a boiling heat into sugar. Gelatine consists of carbon, 47·88 ; hydrogen, 7·91 ; oxygen, 27·21.

Gelatine is produced by boiling the skin of animals in water, which in its crude but solid state is called *glue*, and when a tremulous semi-liquid, *size*. See those articles.

A fine gelatine for culinary uses is prepared and sold as Nelson's patent gelatine. It is thus prepared:—After washing the parings, &c., of skin, he scores their surfaces, and then digests them in a dilute caustic soda lye during ten days. They are next placed in an air-tight vat, lined with cement, kept at a temperature of 70° Fahr.; then washed in a revolving cylinder apparatus with plenty of cold water, and afterwards exposed to the fumes of burning sulphur (sulphurous acid) in a wooden chamber. They are now squeezed to expel the moisture, and finally converted into soluble gelatine, by water in earthen vessels, enclosed in steam cases. The fluid gelatine is purified by straining it at a temperature of 100° or 120° Fahr.

A sparkling gelatine has been prepared under a patent granted to Messrs. J. and G. Cox, of Edinburgh. By their process the substance is rendered perfectly pure, while it possesses a gelatinising force superior even to isinglass. It makes a splendid calves'-feet jelly and a milk-white blanc-mange. The patentees also prepare a semi-solid gelatine, resembling jujubes, which readily dissolves in warm water, as also in the mouth, and may be employed to make an extemporaneous jelly.

The gelatine of bones may be extracted best by the combined action of steam and a current of water trickling over their crushed fragments in a properly constructed apparatus. When the gelatine is to be used as an alimentary article, the bones ought to be quite fresh, well preserved in brine, or to be dried strongly by a stove. Bones are best crushed by passing them between grooved iron rolls. The

cast-iron cylinders in which they are to be steamed, should be three times greater in length than in diameter. To obtain 1000 rations of gelatinous soup daily, a charge of four cylinders is required ; each being 3½ feet long, by 14 inches wide, capable of holding 70 lbs. of bones. These will yield each hour about 20 gallons of a strong jelly, and will require nearly 1 gallon of water in the form of steam, and 5 gallons of water to be passed through them in the liquid state. The 5 quarts of jelly produced hourly by each cylinder proceeds from the 1 quart of steam-water and 4 quarts of percolating water.

The boiler should furnish steam of about 223° Fahr., at a pressure of about 4 lbs. on the square inch.

In *fig.* 885 A, B, C, D, represents a vertical section of the cylinder ; G, H, I, K, a section of the basket or cage, as filled with the bruised bones, inclosed in the cylinder ; E, C, C, the pipe which conducts the steam down to the bottom of the cylinder ; L, S, a pipe for introducing water into the interior ; M, a stopcock for regulating the quantity of water (according to the force of the steam pressure within the apparatus), which should be 3½ quarts per hour ; N is a tube of tin plate fitting tightly into the part S of the pipe L ; it is shut at R, and perforated below with a hole ; it is inserted in its place, after the cage full of bones has been introduced. *Fig.* 886 is an elevation of the apparatus. A, B, C, D, represent the four cylinders, raised about 20 inches above the floor, and fixed in their seats by screws ; *h h*, are the lids ; *g g*, tubulures or valves in the lids ; *i*, ring junction of the lid ; *p*, a thermometer ; *f f*, stop-cocks for drawing off the jelly ; *n n* small gutters of tin-plate ; *m*, the general gutter of discharge

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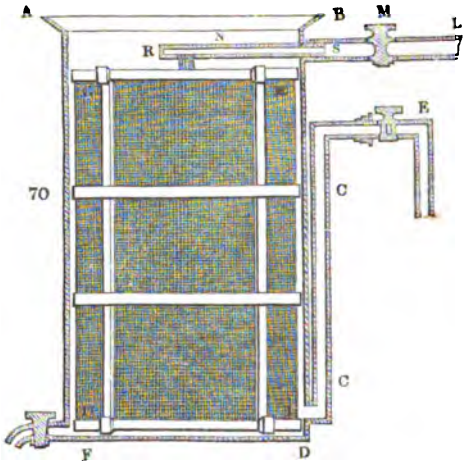

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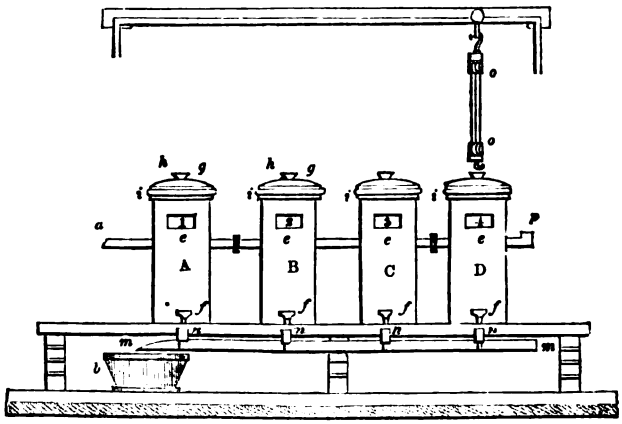

into the cistern *b* ; *o*, a block and tackle for hoisting the cageful of bones in and out. *Fig.* 887 is an end view of the apparatus ; *a*, the main steam-pipe ; *a, b, c, c*, branches that conduct the steam to the bottom of the cylinder ; *o*, the tackle for raising the cage ; *s*, stopcock ; *n*, small gutter ; *m*, main conduit ; *b*, cistern of reception.

When a strong and pure jelly is wished for, the cylinder charged with the bones is to be wrapped in blanket stuff ; and whenever the grease ceases to drop, the stopcock

which admits the cold water is to be shut, as also that at the bottom of the cylinder, which is to be opened only at the end of every hour, and so little as to let the gelatinous solution run out, without allowing any of the steam to escape with it.

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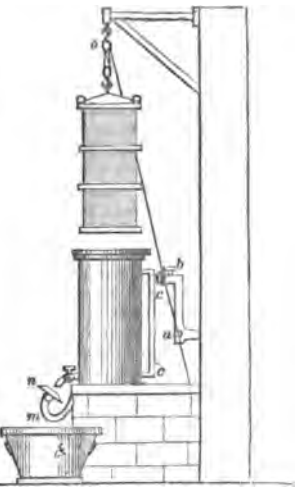


Butchers' meat contains on an average in 100 pounds, 24 of dry flesh, 56 of water, and 20 of bones. These 20 pounds can furnish 6 pounds of alimentary substance in a dry state; whence it appears that, by the above means, one fourth more nutritious matter can be obtained than is usually got. A keen dispute has been carried on for some time in Paris, between the partisans and adversaries of gelatine as an article of food. It is probable that both parties have pushed their arguments too far. Calf's-foot jelly is still deemed a nutritious article by the medical men of this country, at least, though it is not to be trusted to alone, but should have a due admixture or interchange of fibrine, albumen, caseine, &c. See NUTRITION.

French Gelatine is sold in cakes, marked, like those of common glue, with the nets on which they have been dried. This gelatine is made at Paris, from the cuttings of skins used for making white kid gloves; it is coloured red, green, and blue, as well as sold colourless.

Swinbourne's patent refined isinglass is a pure form of gelatine, procured from the skins of calves cut into very thin slices and treated simply with water at or about 200°.

D'Arcet, in his *Reserches sur les Substances nutritive que renferment les Os*, states, that in Paris, bones of all kinds are first digested with hydrochloric acid to extract the phosphate of lime, and then boiled in water under pressure. In this way a nutritious soup is prepared for the hospitals and other pauper establishments. See ISINGLASS.

GEMS are precious stones, which, by their colour, limpidity, lustre, brilliant polish, purity, and rarity, are sought after as objects of dress and decoration. They form the principal part of the crown jewels of kings, not only from their beauty, but because they are supposed to comprise the greatest value in the smallest bulk; for a diamond, no larger than a nut or an acorn, may be the representative sign of the territorial value of a whole country, the equivalent in commercial exchange of a hundred fortunes acquired by severe toils and privations.

Among these beautiful minerals mankind have agreed in forming a select class, to which the title of *gems* or *jewels* has been appropriated; while the term *precious stone* is more particularly given to substances which often occur under a more considerable volume than *fine stones* ever do.

Diamonds, sapphires, emeralds, rubies, topazes, hyacinths, and chrysoberyls, are reckoned the most valuable *gems*.

Crystalline quartz, pellucid, opalescent, or of various hues, amethyst, lapis lazuli; malachite, jasper, agate, &c., are ranked in the much more numerous and inferior class of ornamental stones. These distinctions are not founded upon any strict philosophical principle, but are regulated by a conventional agreement, not very well defined; for it is impossible to subject these creatures of fashion and taste to the rigid subdivisions of science. We have only to consider the value currently attached to them, and take care not to confound two stones of the same colour, but which may be very differently prized by the *virtuoso*.

Since it usually happens that the true gems are in a cut and polished state, or even set in gold or silver, we are thereby unable to apply to them the criteria of mineralogical and chemical science. The cutting of the stone has removed or masked its crystalline character, and circumstances rarely permit the phenomena of double or single refraction to be observed; while the test by the blowpipe is inadmissible. Hence the only scientific resources that remain are the trial by electricity, which is often inconclusive; the degree of hardness, a criterion requiring great experience in the person who employs it; and, lastly, the proof of specific gravity, unquestionably one of the surest means of distinguishing the really fine gems from ornamental stones of similar colour. This proof can be applied only to a stone that is not set; but the richer gems are usually dismounted when offered for sale.

This character of specific gravity may be applied by any person of common intelligence with the aid of a small hydrostatic balance. If, for example, a stone of a fine crimson-red colour be offered for sale as an oriental ruby; the purchaser must ascertain

if it be not a Siberian tourmaline, or ruby spinel. Supposing its weight in air to be 100 grains, if he finds it reduced to 69 grains when weighed in water, he concludes that its bulk is equal to that of 31 grains of water, which is its loss of weight. Now, a real sapphire which weighs 100 grains in air, would have weighed 76·6 in water; a spinel ruby of 100 grains would have weighed 72·2 in water, and a Siberian tourmaline of 100 grains would have weighed only 69 grains in water. The quality of the stone in question, is therefore, determined beyond all dispute, and the purchaser may be thus protected from fraud. See the GEMS respectively.

GEMS, ARTIFICIAL. These are glasses, the material of which they are composed being called Strass.

Strass, the paste or glass which generally forms the principal ingredient of imitation gems, is called after the name of a German jeweller, by whom it was invented, at the commencement of the last century. It is composed of silica, potash, borax, the various oxides of lead, and sometimes of arsenic: chemically it may be regarded as a double silicate of potash and lead.

The silica may be furnished either by rock crystal, white sand, or flint: but, of these, the first is to be preferred, one of the principal considerations in these preparations being the extreme purity of the materials or ingredients employed. In this manufacture, which is of more importance, and attended with greater difficulty than most persons imagine, perfect success (independently of the choice of materials) depends upon the care taken, and the precautions to be observed. No crucibles should be used but those which have been proved, both as regards their composition, their power of withstanding the strongest heat, and their impenetrability to the action of metallic oxides.

All the substances to be melted should be first pulverised, and even ground with the greatest care. It should be remembered that the most perfect mixture can only be effected by numerous siftings, and that a separate sieve should be used for each ingredient, and never be made to serve for different substances. When mixed, the materials should be melted in a crucible placed in the middle of a cylindrical furnace terminated in a dome, the height of which should be 7 feet 6 inches, and its diameter 4 feet 3 inches. The fuel should consist as much as possible of thoroughly dry wood, chopped very small. The melting should be effected by means of a heat raised by degrees, and then steadily maintained, especially at the maximum temperature; then when once the melting has been thoroughly accomplished, which cannot be in less than from twenty to thirty hours, the crucible must be allowed to cool very slowly.

The art of imitating precious stones in paste has amazingly improved since the time of Strass, as was shown by the results of the great Paris exposition of 1855. The imitations, especially as regards certain colours, leave little to be desired; but there is something still in that respect in which the imitation is far from being perfect.

Now that it is proved that the alkalies and vitrifiable earths are oxides of the metals, all that has to be done to obtain the finest effects, is to combine them skilfully, and in their present forms with other artificially prepared metallic oxides, which have undergone the process of vitrification.

Experiments ought to be made with all oxidisable and vitrifiable substances, with the different salts, fluates, phosphates, phosphoric acid, &c.

The following are some of the mixtures generally known, but, it must be observed here that each artist has his own processes, ingredients, and proportions.

Mixtures for Strass.

	1.	2.	3.	4.
	Grains.	Grains.	Grains.	Grains.
Rock crystal - - -	3396·2	3007·8	2897·5	3007·8
Minium - - - -	5280·8	- -	4231·25	—
White lead (pure) - - -	- -	5641·0	- -	5641·0
Potash (pure) - - -	1804·77	1044·0	1625·15	1044·0
Borax - - - - -	232·1	305·0	181·28	301·5
Arsenic - - - - -	10·18	10·18	5·09	—

Common Strass.

Litharge, 77·16; white sand, 57·73; potash, 7·71.

Strass of Douhaut-Wieland.

Sifted rock crystal - -	2897·5	Deutoxide of arsenic -	4·92
Boracic acid - - -	181·18	Potash (purest) - -	1608·53
Minium (purest) - -	4451·37		

English Strass.

Calcined flints	962·5	Calcined borax	361·9
Pure potash	481·25	Fine white lead	120·89

Strass Bastenaire.

	1.	2.	3.	4.	5.
	Grains.	Grains.	Grains.	Grains.	Grains.
White sand treated with hydrochloric acid	1543·23	1543·23	385·8	385·8	385·8
Minium, first quality	6·16	2156·	771·61	925·8	848·65
White potash, well calcined	370·32	493·76	108·2	61·72	154·32
Calcined borax	308·64	185·16	- -	92·58	123·45
Crystallised nitrate of potash (nitre)	185·16	- -	123·44	- -	77·16
Peroxide of manganese	61·72	- -	- -	154·32	- -
Deutoxide of arsenic	- -	9·26	- -	23·15	- -

VARIOUSLY COLOURED STRASS.

Topaz: No. 1.

Whitest strass, 842·079; glass of antimony, 36·421; purple of Cassius, 0·738.

Another.

White lead of Clichy, 771·6; flints calcined and pulverised, 771.6.

Another.

White sand, well dressed	1543·23	Oxide of silver	77·16
Borax, calcined	138·88	Calcined potash	493·76
Minium	2237·64		

Sapphire: Whitest strass, 3858·087; pure oxide of cobalt, 57·708.

Ditto: another. Very fine strass, 481·25; purest oxide of cobalt, 1·697.

Emerald, No. 1. Strass, 3858.087; pure green oxide of copper, 35·643; oxide of chrome, 1·697.

Ditto: ordinary. Strass, 7716·174; acetate of copper, 61·11: oxide of iron, 12·731.

Ditto: another. Strass, 481·25; oxide of copper precipitated from the nitrate by potash, 334·45.

EMERALDS (*Bastenaire*).

	1.	2.
	Grains.	Grains.
Well washed sand	154·32	154·32
Minium	231·48	231·48
White potash, calcined	46·29	77·16
Borax, calcined	30 86	30·86
Yellow oxide of antimony	7·71	- -
Pure oxide of cobalt	1·54	- -
Green oxide of chrome	- -	3·85

AMETHYST (*Bastenaire*).

	Pale.	Deep coloured.
	Grains.	Grains.
Strass	7716·17	3858·08
Oxide of manganese	20·39	36·55
Oxide of cobalt	0·848	20·39
Purple of Cassius	- -	0·848

Aquamarine.

Strass, 2913·50; Glass of antimony, 20·370; Oxide of cobalt, 1·265.

Syrian Garnet.

	1.	2.
	Grains.	Grains.
Strass - - - - - - - -	427·931	484·25
Glass of antimony - - - -	215·815	- -
Purple of Cassius - - - - -	1·697	2·150
Oxide of manganese - - - -	1·697	- -

Observations. For topaz, No. 1, the clearest and most transparent glass of antimony should be used. Frequently this mixture only yields an opaque mass, translucent on the edges, and transmitting in thin fragments a red colour when held between the eye and the light: in that case rubies may be made of it.

To make them, a portion of the topaz material is taken, and mixed with eight parts of fine strass: these are melted in a Hessian crucible for thirty hours in a potter's furnace, and the result is a beautiful yellow glass-like strass, which, when cut, produces an imitation of the finest oriental rubies.

These may be made of another tint by using the following proportions:—

Strass, 2411·25; oxide of manganese, 61·310.

In the emerald, No. 1, by increasing the proportion of chrome or oxide of copper, and mixing with it oxide of iron, the green shade may be varied, and the peridot or deep tinted emerald may be imitated.

The manufacture of artificial gems has acquired an extreme development; immense factories are established at Septmoncal in the Jura, furnishing employment to more than 100 work-people, who produce fabulous quantities.

Many ingenious persons in Paris vie with one another in bringing to perfection the most perfect processes, and produce truly surprising results. M. Savary especially, in his magnificent collections, and his perfect imitation of celebrated diamonds, has arrived at a degree of excellence which, apparently, can scarcely be surpassed.

We have alluded only to those imitations of gems in glass of which a large portion of the cheap jewellery is formed. Some very successful attempts have been made to manufacture true gems by an artificial process. M. Ebelmen has done much in this direction, and M. Henri Sainte-Claire Deville and M. Henri Caron communicated to the Academy of Sciences of Paris, in April 1858, a process which they had discovered for the production of a number of the gems which belong to the corundum class, as the ruby, sapphire, &c. Essentially, the process consisted in exposing the fluoride of aluminium, mixed with a little charcoal and boracic acid, in a black lead crucible, protected from the action of the air, to a white heat for about an hour. For details of the process see *Comptes Rendus, Annales de Chimie.*

GENEVA. A grain spirit flavoured with juniper berries, manufactured extensively in Holland; hence it is frequently called HOLLANDS.

GENTIAN. *Gentiana lutea.* The common or yellow gentian, which is said to owe its name to Gentius king of Illyria, who introduced it as a medicine about 170 years before Christ.

The roots of the gentian are collected and dried by the peasants of Switzerland, the Tyrol, and in the Auvergne.

The bitter of the gentian is agreeable and aromatic; it is much used in medicine, and has on some occasions been employed instead of hops in beer.

GEODE. A rounded nodule of stone, containing a cavity usually lined with crystals. Geodes frequently consist of agate, calcedony, &c.

GEOGNOSY, γη, the earth, and γνωσις, knowledge,—means the science of the substances which compose the earth's crust. It originated with the German mineralogists.

GEOLOGY, γη, the earth, and λογος, a discourse. The science which treats of the structure of the earth, and of the causes which have produced its present physical features.

GERHARDT'S ANHYDROUS ACETIC ACID. See ACETIC ACID, and refer to Ure's *Dictionary of Chemistry.*

GERMAN BLACK. See FRANKFORT BLACK.

GERMAN SILVER. See ALLOY and COPPER. M. Gersdorf, of Vienna, states that

the proportion of the metals in this alloy should vary according to the uses for which it is destined. When intended as a substitute for silver, it should be composed of 25 parts of nickel, 25 of zinc, and 50 of copper. An alloy better adapted for rolling consists of 25 of nickel, 20 of zinc, and 60 of copper. Castings, such as candlesticks, bells, &c., may be made of an alloy, consisting of 20 of nickel, 20 of zinc, and 60 of copper; to which 3 of lead are added. The addition of 2 or 2½ of iron (in the shape of tin plate?) renders the alloys much whiter, but, at the same time, harder and more brittle.

Keferstein has given the following analysis of the genuine German silver, as made from the original ore found in Hildburghausen, near Suhl, in Henneberg:—

Copper	40·4
Nickel	31·6
Zinc	25·4
Iron	2·6
	100·0

Chinese pakfong, a white alloy, according to the same authority, consists of 5 parts of copper, alloyed with 7 parts of nickel, and 7 parts of zinc.

The best alloy for making bearings, bushes, and steps for the steel or iron gudgeons, and pivots of machinery to run in, is said to consist of 90 parts of copper, 5 of zinc, and 5 of antimony.

GERMAN STEEL. A metal made of a white iron in forges where charcoal is employed, the ores used being either bog-iron ore or the sparry carbonate.

GERMAN TINDER. See AMADOU.

GERMINATION. (Eng. and Fr.; *Das Keimen*, Germ,) The first indication of vital force in the embryo plant. The seed being placed in the soil, a proper temperature existing, and a due quantity of water being supplied, a chemical action is established, and heat is developed. In fact, a slow combustion takes place, during which oxygen is combined with carbon, and carbonic acid is liberated. The starch of the grain, by the process of germination, is converted into sugar by taking into combination one equivalent of the elements of water. While this operation is progressing, the embryo enlarges, sending down its root radicle into the soil, and forcing upwards, towards the light, the cotyledons or leaf lobes, and the plumule.

These phenomena of the commencement of vegetable life can be well studied in the process of *Malting*, in which the barley, by the conversion of its starch into sugar, becomes malt.

The direct action of sunlight is injurious to the germinating seed, consequently it is a law of nature that a dark soil should be the bed in which this remarkable operation commences, and is continued until the first leaves appear above the soil. In the process of malting (which see), care is taken that the floors upon which the germination is established are but dimly illuminated.

GEROPIGA. A factitious liquor, imported from Portugal and used in this country for the adulteration of wines. It is sometimes spelt JERUPIGA. It appears to be a compound of unfermented grape juice, brandy, sugar, and colouring matter. This compound is used even more extensively in the United States than in this country. — (*M'Culloch.*)

GIG MACHINES, are rotatory drums, mounted with thistles or wire teeth for teazling cloth. See WOOLLEN MANUFACTURE.

GILDING. (*Dorure*, Fr.; *Vergoldung*, Germ.) This art consists in covering bodies with a thin coat of gold, which may be done either by mechanical or chemical means. The mechanical mode is the application of gold leaf or gold powder to various surfaces, and their fixation by various means. Thus gold may be applied to wood, plaster, pasteboard, leather; and to metals, such as silver, copper, iron, tin, and bronze; so that gilding, generally speaking, includes several arts, exercised by very different classes of tradesmen.

I. MECHANICAL GILDING. — Oil gilding is the first method under this head, as oil is the fluid most generally used in the operation of this mechanical art. The following process has been much extolled at Paris.

1. A coat of *impression* is to be given first of all, namely, a coat of white lead paint, made with drying linseed oil, containing very little oil of turpentine.

2. Calcined ceruse is to be ground very well with unboiled linseed oil, and tempered with essence of turpentine, in proportion as it is laid on. Three or four coats of this *hard tint* are to be applied evenly on the ornaments, and the parts which are to be most carefully gilded.

3. The *Gold colour* is then to be smoothly applied. This is merely the dregs of the colours, ground and tempered with oil, which remain in the little dish in which painters

clean their brushes. This substance is extremely rich and gluey; after being ground up, and passed through fine linen cloth, it forms the ground for gold leaf.

4. When the gold colour is dry enough to catch hold of the leaf gold, this is spread on the cushion, cut into pieces and carefully applied with the pallet knife, pressed down with cotton, and on the small ornaments with a fine brush.

5. If the gildings be for outside exposure, as balconies, gratings, statues, &c., they must not be varnished, as simple oil gilding stands better; for when it is varnished, a bright sun-beam acting after heavy rain, gives the gilding a jagged appearance. When the objects are inside ones, a coat of spirit varnish may be passed over the gold leaf, then a glow from the gilder's chafing dish may be given, and finally a coat of oil varnish. The workman who causes the chafing dish to glide in front of the varnished surface, must avoid stopping for an instant opposite any point, otherwise he would cause the varnish to boil and blister. This heat brings out the whole transparency of the varnish, and lustre of the gold.

Oil Gilding is employed with varnish polish, upon equipages, mirror-frames, and other furniture. The following method is employed by eminent gilders at Paris:—

1. White lead, with half its weight of yellow ochre, and a little litharge, are separately ground very fine; and the whole is then tempered with linseed oil, thinned with essence of turpentine, and applied in an evenly coat, called *impression*.

2. When this coat is quite dry, several coats of the hard tint are given, even so many as 10 or 12, should the surface require it for smoothing and filling up the pores. These coats are given daily, leaving them to dry in the interval in a warm sunny exposure.

3. When the work is perfectly dry, it is first softened down with pumice stone and water, afterwards with worsted cloth and very finely powdered pumice, till the *hard tint* give no reflection, and be smooth as glass.

4. With a camel's hair brush, there must be given lightly and with a gentle heat, from 4 to 5 coats at least, and even sometimes double that number, of fine lac varnish.

5. When these are dry, the grounds of the pannels and the sculptures must be first polished with shave-grass (*de la prêle*); and next with putty of tin and tripoli, tempered with water, applied with woollen cloth; by which the varnish is polished till it shines like a mirror.

6. The work thus polished is carried into a hot place, free from dust, where it receives very lightly and smoothly, a thin coat of *gold colour*, much softened down. This coat is passed over it with a clean soft brush, and the thinner it is the better.

7. Whenever the gold colour is dry enough to take the gold, which is known by laying the back of the hand on a corner of the frame work, the gilding is begun and finished as usual.

8. The gold is smoothed off with a very soft brush, one of camel's hair for example, of three fingers' breadth; after which it is left to dry for several days.

9. It is then varnished with a spirit of wine varnish; which is treated with the chafing dish as above described.

10. When this varnish is dry, two or three coats of copal, or oil of varnish, are applied, at intervals of two days.

11. Finally, the pannels are polished with a worsted cloth, imbued with tripoli and water, and lustre is given by friction with the palm of the hand, previously softened with a little olive oil, taking care not to rub off the gold.

In this country, *Burnished gilding* is practised by first giving a ground of size whiting, in several successive coats; next applying gilding size; and then the gold leaf, which is burnished down with agate, or a dog's tooth.

Gilding in distemper of the French, is the same as our burnished gilding. Their process seems to be very elaborate, and the best consists of 17 operations; each of them said to be essential.

1. *Encollage*, or the *Glue coat.* To a decoction of wormwood and garlic in water, strained through a cloth, a little common salt, and some vinegar are added. This composition, as being destructive of worms in wood, is mixed with as much good glue; and the mixture is spread in a hot state, with a brush of boar's hair. When plaster or marble is to be gilded, the salt must be left out of the above composition, as it is apt to attract humidity in damp places, and to come out as a white powder on the gilding. But the salt is indispensable for wood. The first glue coating is made thinner than the second.

2. *White preparation.* This consists in covering the above surface, with 8, 10, or 12 coats of Spanish white, mixed up with strong size, each well worked on with the brush, and in some measure incorporated with the preceding coat, to prevent their peeling off in scales.

3. *Stopping up* the pores, with thick whiting and glue, and smoothing the surface with dog-skin.

4. Polishing the surface with pumice-stone and very cold water.

5. *Reparation*; in which a skilful artist retouches the whole.

6. *Cleansing*; with a damp linen rag, and then a soft sponge.

7. *Prêler.* This is rubbing with horse's tail (*shave-grass*) the parts to be yellowed, in order to make them softer.

8. *Yellowing.* With this view *yellow ochre* is carefully ground in water, and mixed with transparent colourless size. The thinner part of this mixture is applied hot over the white surface with a fine brush, which gives it a fine yellow hue.

9. *Ungraining*; consists in rubbing the whole work with shave-grass, to remove any granular appearance.

10. *Coat of assiette*; *trencher coat.* This is the composition on which the gold is to be laid. It is composed of Armenian bole, 1 pound; bloodstone (hematite), 2 ounces; and as much galena; each separately ground in water. The whole are then mixed together, and ground up with about a spoonful of olive oil. The *assiette* well made and applied gives beauty to the gilding. The *assiette* is tempered with a white sheep-skin glue, very clear and well strained. This mixture is heated and applied in three successive coats, with a very fine long-haired brush.

11. *Rubbing*, with a piece of dry, clean linen cloth; except the parts to be burnished, which are to receive other two coats of *assiette* tempered with glue.

12. *Gilding.* The surface being damped with cold water (iced in summer) has then the gold leaf applied to it. The hollow grounds must always be gilded before the prominent parts. Water is dexterously applied by a soft brush, immediately behind the gold leaf, before laying it down, which makes it lie smoother. Any excess of water is then removed with a dry brush.

13. *Burnishing*, with bloodstone.

14. *Deadening.* This consists in passing a thin coat of glue, slightly warmed, over the parts that are not to be burnished.

15. *Mending*; that is, moistening any broken points with a brush, and applying bits of gold leaf to them.

16. The *vermeil* coat. Vermeil is a liquid which gives lustre and fire to the gold: and makes it resemble *or-moulu.* It is composed as follows: 2 ounces of annotto, 1 ounce of gamboge, 1 ounce of vermilion, half an ounce of dragon's blood, 2 ounces of salt of tartar, and 18 grains of saffron, are boiled in a litre (2 pints English) of water, over a slow fire, till the liquid be reduced to a fourth. The whole is then passed through a silk or muslin sieve. A little of this is made to glide lightly over the gold, with a very soft brush.

17. *Repassage*; is passing over the dead surfaces a second coat of deadening glue, which must be hotter than the first. This finishes the work, and gives it strength.

Leaf gilding; on paper or vellum, is done by giving them a coat of gum water or fine size, applying the gold leaf ere the surfaces be hard dry, and burnishing with agate.

Gold lettering, on bound books, is given without size, by laying the gold leaf on the leather, and imprinting it with hot brass types.

The *edges of the leaves of books are gilded*, while they are in the press where they have been cut smooth, by applying a solution of isinglass in spirits, and laying-on the gold when the edges are in a proper state of dryness. The French workmen employ a ground of Armenian bole, mixed with powdered sugar-candy, by means of white of egg. This ground is laid very thin upon the edges, after fine size or gum water has been applied; and when the ground is dry it is rubbed smooth with a wet rag, which moistens it sufficiently to take the gold.

Japanners' gilding is done by sprinkling or daubing with wash leather, some gold powder over an oil sized surface, mixed with oil of turpentine. This gives the appearance of frosted gold. The gold powder may be obtained, either by precipitating gold from its solution in *aqua regia* by a solution of pure sulphate of iron, or by evaporating away the mercury from some gold amalgam.

II. Chemical Gilding, or the application of gold by chemical affinity to metallic surfaces.

A compound of copper with one seventh of brass is the best metal for gilding on; copper by itself being too soft and dark coloured. Ordinary brass, however, answers very well. We shall describe the process of wash gilding, with M. D'Arcet's late improvements, now generally adopted in Paris.

Wash gilding, consists in applying evenly an amalgam of gold to the surface of a copper alloy, and dissipating the mercury with heat, so as to leave the gold film fixed. The surface is afterwards burnished or deadened at pleasure. The gold ought to be

quite pure, and laminated to facilitate its combination with the mercury; which should also be pure.

Preparation of the amalgam.—After weighing the fine gold, the workman puts it in a crucible, and as soon as this becomes faintly red, he pours in the requisite quantity of mercury; which is about 8 to 1 of gold. He stirs up the mixture with an iron rod, bent hookwise at the end, leaving the crucible on the fire till he perceives that all the gold is dissolved. He then pours the amalgam into a small earthen dish containing water, washes it with care, and squeezes out of it with his fingers all the running mercury that he can. The amalgam that now remains on the sloping sides of the vessel is so pasty as to preserve the impression of the fingers. When this is squeezed in a shamoy leather bag, it gives up much mercury; and remains an amalgam, consisting of about 33 of mercury, and 57 of gold, in 100 parts. The mercury which passes through the bag, under the pressure of the fingers, holds a good deal of gold in solution; and is employed in making fresh amalgam.

Preparation of the mercurial solution. — The amalgam of gold is applied to brass, through the intervention of pure nitric acid, holding in solution a little mercury.

100 parts of mercury, and 110 parts by weight of pure nitric acid, specific gravity 1·33, are to be put into a glass matrass. On the application of a gentle heat the mercury dissolves with the disengagement of fumes of nitrous gas, which must be allowed to escape into the chimney. This solution is to be diluted with about 25 times its weight of pure water, and bottled up for use.

1. *Annealing.* — The workman anneals the piece of bronze after it has come out of the hands of the turner and engraver. He sets it among burning charcoal, or rather peats, which have a more equal and lively flame; covering it quite up, so that it may be oxidised as little as possible, and taking care that the thin parts of the piece do not become hotter than the thicker. This operation is done in a dark room, and when he sees the piece of a cherry red colour, he removes the fuel from about it, lifts it out with long tongs, and sets it to cool slowly in the air.

2. The *decapage.* — The object of this process is to clear the surface from the coat of oxide which may have formed upon it. The piece is plunged into a bucket filled with extremely dilute sulphuric acid; it is left there long enough to allow the coat of oxide to be dissolved, or at least loosened; and it is then rubbed with a hard brush. When the piece becomes perfectly bright, it is washed and dried. Its surface may, however, be still a little variegated; and the piece is therefore dipped in nitric acid, specific gravity 1·33, and afterwards rubbed with a long-haired brush. The addition of a little common salt to the dilute sulphuric acid would probably save the use of nitric acid, which is so apt to produce a new coat of oxide. It is finally made quite dry (after washing in pure water), by being rubbed well with tanners' dry bark, sawdust, or bran. The surface should now appear somewhat depolished; for when it is very smooth, the gold does not adhere so well.

3. *Application of the amalgam.* — The gilder's *scratch-brush* or pencil, made with fine brass wire, is to be dipped into the solution of nitrate of mercury, and is then to be drawn over a lump of gold amalgam, laid on the sloping side of an earthen vessel, after which it is to be applied to the surface of the brass. This process is to be repeated, dipping the brush into the solution, and drawing it over the amalgam, till the whole surface to be gilded is coated with its just proportion of gold. The piece is then washed in a body of water, dried, and put to the fire to volatilise the mercury. If one coat of gilding be insufficient, the piece is washed over anew with amalgam, and the operation recommenced till the work prove satisfactory.

4. *Volatilisation of the mercury.* —Whenever the piece is well coated with amalgam, the gilder exposes it to glowing charcoal, turning it about, and heating it by degrees to the proper point; he then withraws it from the fire, lifts it with long pincers, and, seizing it in his left hand, protected by a stuffed glove, he turns it over in every direction, rubbing and striking it all the while with a long-haired brush, in order to equalise the amalgam. He now restores the piece to the fire, and treats it in the same way till the mercury be entirely volatilised, which he recognises by the hissing sound of a drop of water let fall on it. During this time he repairs the defective spots, taking care to volatilise the mercury very slowly. The piece, when thoroughly coated with gold, is washed, and scrubbed well with a brush in water acidulated with vinegar.

If the piece is to have some parts burnished, and others dead, the parts to be burnished are covered with a mixture of Spanish white, bruised sugar-candy, and gum dissolved in water. This operation is called in French *epargner* (*protecting*). When the gilder has *protected* the burnished points, he dries the piece, and carries the heat high enough to expel the little mercury which might still remain on it. He then plunges it, while still a little hot, in water acidulated with sulphuric acid, washes it, dries it, and gives it the burnish.

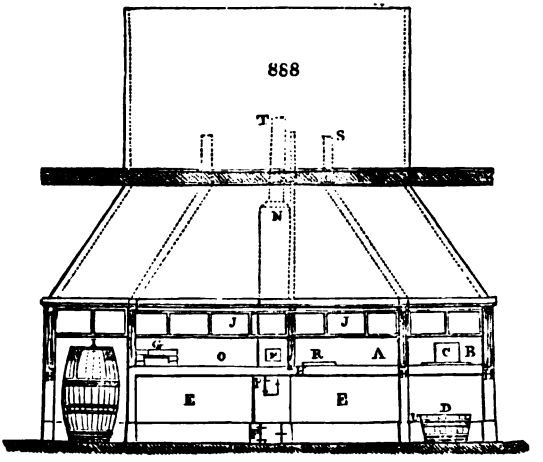
5. The *burnish* is given by rubbing the piece with burnishers of hematite (blood-

stone). The workman dips his burnisher in water sharpened with vinegar, and rubs the piece always in the same direction backwards and forwards, till it exhibits a fine polish, and a complete metallic lustre. He then washes it in cold water, dries it with fine linen cloth, and concludes the operation by drying it slowly on a grating placed above a chafing dish of burning charcoal.

6. The *deadening* is given as follows. The piece, covered with the *protection* on those parts that are to be burnished, is attached with an iron wire to the end of an iron rod, and is heated strongly so as to give a brown hue to the *epargne* by its partial carbonisation. The gilded piece assumes thus a fine tint of gold; and is next coated over with a mixture of sea salt, nitre and alum, fused in the water of crystallisation of the latter salt. The piece is now restored to the fire, and heated till the saline crust which covers it becomes homogenous, nearly transparent, and enters into true fusion. It is then taken from the fire and suddenly plunged into cold water, which separates the saline crust, carrying away even the coat of *epargne*. The piece is lastly passed through very weak nitric acid, washed in a great body of water, and dried by exposure either to the air, over a drying stove, or with clean linen cloths.

7. *Of or-moulu colour.*—When it is desired to put a piece of gilded bronze into *or-moulu* colour, it must be less scrubbed with the scratch-brush than usual, and made to *come back again* by heating it more strongly than if it were to be deadened, and allowing it then to cool a little. The *or-moulu* colouring is a mixture of hematite, alum, and sea salt. This mixture is to be thinned with vinegar, and applied with a brush so as to cover the gilded brass, with reserve of the burnished parts. The piece is then put on glowing coals, urged a little by the bellows, and allowed to heat till the colour begins to blacken. The piece ought to be so hot that water sprinkled on it may cause a hissing noise. It is then taken from the fire, plunged into cold water, washed, and next rubbed with a brush dipped in vinegar, if the piece be smooth, but if it be chased, weak nitric acid must be used. In either case, it must be finally washed in a body of pure water, and dried over a gentle fire.

8. *Of red gold colour.*—To give this hue, the piece after being coated with amalgam, and heated, is in this hot state to be suspended by an iron wire, and tempered with the composition known under the name of gilder's wax; made with yellow wax, red ochre, verdigris, and alum. In this state it is presented to the flame of a wood fire, is heated strongly, and the combustion of its coating is favoured by throwing some drops of the wax mixture into the burning fuel. It is now turned round and round over the fire, so that the flame may act equally. When all the wax of the colouring is burned away, and when the flame is extinguished, the piece is to be plunged in water, washed, and scrubbed with the scratch-brush and pure vinegar. If the colour is not beautiful, and quite equal in shade, the piece is coated with verdigris dissolved in vinegar, dried over a gentle fire, plunged in water, and scrubbed with pure vinegar, or even with a little weak nitric acid if the piece exhibit too dark a hue. It is now washed, burnished, washed anew, wiped with linen cloth, and finally dried over a gentle fire.



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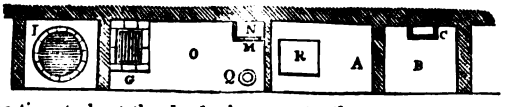


889

The following is the outline of a complete gilding factory, as now fitted up at Paris.

Figs. 888, 889, front elevation and plan of a complete gilding workshop.

P. Furnace of *appel*, or draught, serving at the same time to heat the deadening pan (*poêlon au mat*).

F. Ash-pit of this furnace.

N. Chimney of this furnace constructed of bricks, as far as the contraction of the

great chimney S of the forge, and which is terminated by a summit pipe rising 2 or 3 yards above this contraction.

B. Forge for annealing the pieces of bronze; for drying the gilded pieces, &c.

C. Chimney of communication between the annealing forge B, and the space D below the forge. This chimney serves to carry the noxious fumes into the great vent of the factory.

U. Bucket for the brightening operation.

A. Forge for passing the amalgam over the piece.

B. Shelf for the brushing operations.

E E. Coal cellarets.

O. Forge for the deadening process.

G. Furnace for the same.

M. An opening into the furnace of *appel*, by which vapours may be let off from any operation by taking out the plug at M.

I. Cask in which the pieces of gilded brass are plunged for the deadening process. The vapours rising thence are carried up the general chimney.

J J. Casement with glass panes, which serves to contract the opening of the hearths, without obstructing the view. The casement may be rendered movable to admit larger objects.

H H. Curtains of coarse cotton cloth, for closing at pleasure, in whole or part, one or several of the forges or hearths, and for quickening the current of air in the places where the curtains are not drawn.

Q. Opening above the draught furnace, which serves for the heating of the *poêlon au mat* (deadening pan).

Gilding on polished iron and steel. — If a nearly neutral solution of gold in muriatic acid be mixed with sulphuric ether, and agitated, the ether will take up the gold, and float above the denser acid. When this auriferous ether is applied by a hair pencil to brightly polished iron or steel, the ether flies off, and the gold adheres. It must be fixed by polishing with the burnisher. This gilding is not very rich or durable. In fact the affinity between gold and iron is feeble, compared to that between gold and copper or silver. But polished iron, steel, and copper, may be gilded with heat, by gold leaf. They are first heated till the iron takes a bluish tint, and till the copper has attained to a like temperature; a first coat of gold leaf is now applied, which is pressed gently down with a burnisher, and then exposed to a gentle heat. Several leaves either single or double are thus applied in succession, and the last is burnished down cold.

Mr. Elkington obtained a patent, in June, 1836, for gilding copper, brass, &c., by means of potash or soda combined with carbonic acid, and with a solution of gold. Dissolve, says he, 5 oz. troy of fine gold in 52 oz. avoirdupoise of nitro-muriatic acid of the following proportions: viz. 21 oz. of pure nitric acid, of spec. grav. 1·45, 17 oz. of pure muriatic acid, of spec. grav. 1·15, with 14 oz. of distilled water.

The gold being put into the mixture of acids and water, they are to be heated in a glass or other convenient vessel till the gold is dissolved; and it is usual to continue the application of heat after this is effected, until a reddish or yellowish vapour ceases to rise.

The clear liquid is to be carefully poured off from any sediment which generally appears, and results from a small portion of silver, which is generally found in alloy with gold. The clear liquid is to be placed in a suitable vessel of stone; pottery ware is preferred. Add to the solution of gold 4 gallons of distilled water, and 20 pounds of bicarbonate of potash of the best quality; let the whole boil moderately for 2 hours, the mixture will then be ready for use.

The articles to be gilded having been first perfectly cleaned from scale or grease, they are to be suspended on wires, conveniently for a workman to dip them in the liquid, which is kept boiling. The time required for gilding any particular article will depend on circumstances, partly on the quantity of gold remaining in the liquid, and partly on the size and weight of the article; but a little practice will readily give sufficient guidance to the workman.

Supposing the articles desired to be gilded be brass or copper buttons, or small articles for gilt toys, or ornaments of dress, such as earrings or bracelets, a considerable number of which may be strung on a hoop, or bended piece of copper or brass wire, and dipped into the vessel containing the boiling liquid above described, and moved therein, the requisite gilding will be generally obtained in from a few seconds to a minute; this is when the liquid is in the condition above described, and depending on the quality of the gilding desired; but if the liquid has been used some time, the quantity of gold will be lessened, which will vary the time of operating to produce a given effect, or the colour required, all of which will quickly be observed by the workman; and by noting the appearance of the articles from time to time, he will

know when the desired object is obtained, though it is desirable to avoid as much as possible taking the articles out of the liquid.

When the operation is completed, the workman perfectly washes the articles so gilded with clean water; they may then be submitted to the usual process of colouring.

If the articles be cast figures of animals, or otherwise of considerable weight, compared with the articles above mentioned, the time required to perform the process will be greater.

In case it is desired to produce what is called a dead appearance, it may be performed by several processes: the one usually employed is to dead the articles in the process of cleaning, as practised by brass founders and other trades; it is produced by an acid, prepared for that purpose, sold by the makers under the term "deading aquafortis," which is well understood.

It may also be produced by a weak solution of nitrate of mercury, applied to the articles previous to the gilding process, as is practised in the process of gilding with mercury, previous to spreading the amalgam, but generally a much weaker solution; or the articles having been gilded may be dipped in a solution of nitrate of mercury, and submitted to heat to expel the same, as is practised in the usual process of gilding.

Cold gilding. — Sixty grains of fine gold and 12 of rose copper are to be dissolved in two ounces of aqua regia. When the solution is completed, it is to be dropped on clean linen rags, of such bulk as to absorb all the liquid. They are then dried, and burned into ashes. These ashes contain the gold in powder.

When a piece is to be gilded, after subjecting it to the preliminary operations of softening or annealing and brightening, it is rubbed with a moistened cork, dipped in the above powder, till the surface seems to be sufficiently gilded. Large works are thereafter burnished with pieces of hematite, and small ones with steel burnishers, along with soap water.

In gilding small articles, as buttons, with amalgam, a portion of this is taken equivalent to the work to be done, and some nitrate of mercury solution is added to it in a wooden trough; the whole articles are now put in, and well worked about with a hard brush, till their surfaces are equably coated. They are then washed, dried, and put altogether into an iron frying-pan, and heated till the mercury begins to fly off, when they are turned out into a cap, in which they are tossed and well stirred about with a painter's brush. The operation must be repeated several times for a strong gilding. The surfaces are finally brightened by brushing them along with small beer or ale grounds.

For the processes of gilding by electro-chemical means, see ELECTROTYPE.

GIMP, or GYMP, a silk, woollen, or cotton twist, with often a metallic wire, but sometimes a coarse thread running through it; it is much used in coat-lace making.

GIN, or *Geneva*, from *Genievre* (juniper), is an ardent spirit manufactured in London, and other places, in great quantities, and flavoured generally with juniper berries. It is also made in Holland, and hence called Hollands gin in this country, to distinguish it from British gin. The materials employed in the distilleries of Schiedam, are two parts of unmalted rye from Riga, weighing about 54 lbs. per bushel, and one part of malted bigg, weighing about 37 lbs. per bushel. The mash tun, which serves also as the fermenting tun, has a capacity of nearly 700 gallons, being about 5 feet in diameter at the mouth, rather narrower at the bottom, and 4½ feet deep; the stirring apparatus is an oblong rectangular iron grid made fast to the end of a wooden pole. About a barrel, = 36 gallons of water, at a temperature of from 162° to 168° (the former heat being best for the most highly dried rye), are put into the mash tun for every 1½ cwt. of meal, after which the malt is introduced and stirred, and lastly the rye is added. Powerful agitation is given to the magma till it becomes quite uniform; a process which a vigorous workman piques himself upon executing in the course of a few minutes. The mouth of the tun is immediately covered over with canvas, and further secured by a close wooden lid, to confine the heat; it is left in this state for two hours. The contents being then stirred up once more, the *transparent* spent wash of a preceding mashing is first added, and next as much cold water as will reduce the temperature of the whole to about 85° F. The best Flanders yeast, which had been brought, for the sake of carriage, to a doughy consistence by pressure, is now introduced to the amount of one pound for every 100 gallons of the mashed materials.

The gravity of the fresh wort is usually from 33 to 38 lbs. per Dicas' hydrometer; and the fermentation is carried on from 48 to 60 hours, at the end of which time the attenuation is from 7 to 4 lbs, that is, the specific gravity of the supernatant wash is from 1·007 to 1·004.

The distillers are induced, by the scarcity of beer-barm in Holland, to skim off a quantity of the yeast from the fermenting tuns, and to sell it to the bakers, whereby they obstruct materially the production of spirit, though they probably improve its quality, by preventing its impregnation with yeasty particles; an unpleasant result which seldom fails to take place in the whisky distilleries of the United Kingdom.

On the third day after the fermenting tun is set, the wash containing the grains is transferred to the still, and converted into low wines. To every 100 gallons of this liquor, two pounds of juniper berries, from 3 to 5 years old, being added, along with about one quarter of a pound of salt, the whole are put into the low wine still, and the fine Hollands spirit is drawn off by a gentle and well-regulated heat, till the magma becomes exhausted; the first and the last products being mixed together; whereby a spirit, 2 to 3 per cent. above our hydrometer proof, is obtained, possessing the peculiar fine aroma of gin. The quantity of spirit varies from 18 to 21 gallons per quarter of grain; this large product being partly due to the employment of the spent wash of the preceding fermentation; an addition which contributes at the same time to improve the flavour.

London gin is, as we have stated, a corn spirit, which is, however, rendered sweet and cordial-like, by the use of several injurious substances. Plymouth gin, as manufactured by Coates and Co. of Plymouth, is a far purer spirit. The rectifiers employ a pure grain spirit, and flavour with the wash of the whisky distilleries. Mr. Brande has given the following table of the quantities of alcohol (sp. gr. at 60 F., 0·825) contained in different ardent spirits.

Proportion of Alcohol in ardent Spirits.

	In 100 parts.
Brandy	55·39 by measure.
Rum	53·68 „
Gin	51·60 „
Whisky, Scotch	54·32 „
Do. Irish	53·20 „

When wash is distilled, the fluid that comes over is called *singlings*, or *low wines*. It is concentrated or *doubled* by a second distillation, and becomes *raw corn spirit*; this is sold to the rectifier at 11 or 25 per cent. over proof.

GINGER BEER. Boil 65 gallons of river water, 1½ cwt. of the best loaf sugar, and 5 lbs. of the best race ginger, bruised, half an hour; then add the whites of 10 eggs, beaten to a froth with 2 ounces of dissolved isinglass. Stir it well in, and boil 20 minutes longer, skimming it the whole time. Then add the thin rinds of 50 lemons, boiling them 10 minutes more. Cut 28 lbs. of good Malaga raisins in half, take away the stones and stalks, and put them, with the juice of the lemon, strained, into the hogshead. Strain the hot liquor into a cooler, and when it has stood two hours and is settled, draw it off the lees, clear, and put it into the cask; filter the thick and fill up with it. Leave the bung out, and when at the proper temperature, stir 3 quarts of thick fresh ale yeast well into it; put on the bung lightly, and let it ferment 6 or 7 days, filling up with liquor as it ferments over. When the fermentation has ceased, pour in 6 quarts of French brandy, and 8 ounces of the best isinglass, dissolved in a gallon of the wine; then secure the bung effectually, and paste paper over it, &c. Keep it 2 years in a cool cellar, then bottle it, using the best corks, and sealing them; and when it is 4 years old commence using it.

There can be no doubt but that the above receipt by Dr. Ure forms an excellent ginger beer, but it is a totally different thing from the ginger beer of the shops. The following is a good and useful form for its manufacture:—

Barbadoes ginger root	12 ounces.
Tartaric acid	3 ounces.
White sugar	8 pounds.
Gum arabic	8 ounces.
Essence of lemon	2 drachms.
Water	9 gallons.

The ginger root, bruised, is to be boiled for an hour, then the liquor being strained, the tartaric acid and sugar added, boiled and the same removed. The gum arabic dissolved in a separate portion of water, added with the essence of lemons. When the whole has cooled to about 100° Fahr., some fresh yeast is to be added, and the beer carefully fermented. Then bottle for use.

Ginger beer powders are thus prepared:—

White sugar	5 ounces.
Tartaric acid	1½ ounce.
Carbonate of soda	1½ ounce.
Powdered Jamaica ginger	2 drachms.
Essence of Lemon	10 drops.

All the materials are to be carefully dried, and mixed while yet warm, in a warm mortar, and immediately bottled.

If the acid and the carbonate of soda are kept separate, these precautions are not necessary.

GINNING is the name of the operation by which the filaments of cotton are separated from the seeds. See COTTON MANUFACTURE.

GIRASOL. The name given by the French to fire opal. See OPAL.

GLAIRE. The white of egg. This consists according to Gmelin of albumen, 12·0, mucus, 2·7, salts, 0·3, water, 85·0. Glaire or albumen (*ovalbumen*) is distinguished from the albumen of the serum of the blood (*seralbumen*), by its being coagulated by ether. Glaire is used by bookbinders in finishing the backs of books, and for a few other purposes in the arts. See ALBUMEN.

GLANCE COAL, a name given to anthracite, of which there are two varieties, the *slaty* and the *conchoidal*. See ANTHRACITE and COAL.

GLASS (*Verre*, Fr.; *Glas*, Germ.) is a transparent solid formed by the fusion of siliceous and alkaline matter. It was known to the Phœnicians, and constituted for a long time an exclusive manufacture of that people, in consequence of its ingredients, natron, sand, and fuel, abounding upon their coasts. It is certain that the ancient Egyptians were acquainted with glass, for, although we find no mention of it in the writings of Moses, we discover glass ornaments in tombs which are as old as the days of Moses. According to Pliny and Strabo, the glass works of Sidon and Alexandria were famous in their times, and produced beautiful articles, which were cut, engraved, gilt, and stained of the most brilliant colours, in imitation of precious stones. The Romans employed glass for various purposes; and have left specimens in Herculaneum of window-glass, which must have been blown by methods analogous to the modern. The Phœnician processes seem to have been learned by the Crusaders, and transferred to Venice in the 13th century, where they were long held secret, and formed a lucrative commercial monopoly. Soon after the middle of the seventeenth century Colbert enriched France with the blown mirror glass manufacture.

Chance may have had a share in the invention of this curious fabrication, but there were circumstances in the most ancient arts likely to lead to it; such as the fusing and vitrifying heats required for the formation of pottery, and for the extraction of metals from their ores. Pliny ascribes the origin of glass to the following accident. A merchant ship laden with natron being driven upon the coast at the mouth of the river Belus, in tempestuous weather, the crew were compelled to cook their victuals ashore, and having placed lumps of the natron upon the sand, as supports to the kettles, found to their surprise masses of transparent stone among the cinders. The sand of this small stream of Galilee, which runs from the foot of Mount Carmel, was in consequence supposed to possess a peculiar virtue for making glass, and continued for ages to be sought after and exported to distant countries for this purpose. There exists good evidence that the manufacture of glass, and of vitreous glazes is much older than the time ascribed by Pliny.

Agricola, the oldest author who has written technically upon glass, describes furnaces and processes closely resembling those employed at the present day. Neri, Kunckel, Henckel, Pott, Achard, and some other chemists, have since then composed treatises upon the subject; but Neri, Bosc, Antic, Loysel, and Allut, in the *Encyclopédie Methodique*, are the best of the older authorities.

The Venetians were the first in modern times who attained to any degree of excellence in the art of working glass, but the French became eventually so zealous of rivalling them, particularly in the construction of mirrors, that a decree was issued by the court of France, declaring not only that the manufacture of glass should not derogate from the dignity of a nobleman, but that nobles alone should be masters of glass-works. Within the last 30 or 40 years, Great Britain has made rapid advances in this important art, and at the present day her pre-eminence in some departments hardly admits of dispute.

The window-glass manufacture was first begun in England in 1557, in Crutched Friars, London; and fine articles of flint-glass were soon afterwards made in the Savoy House, Strand. In 1635 the art received a great improvement from Sir Robert Mansell, by the use of coal fuel instead of wood. The first sheets of blown glass for looking-glasses and coach windows were made in 1673 at Lambeth, by Venetian artisans employed under the patronage of the Duke of Buckingham.

The casting of mirror-plates was commenced in France about the year 1688, by Abraham Thevart; an invention which gave rise soon afterwards to the establishment of the celebrated works of St. Gobain, which continued for nearly a century the sole place where this highly-prized object of luxury was well made. In cheapness, if not in excellence, the French mirror-plate has been for some time rivalled by the English.

The analysis of modern chemists, which will be detailed in the course of this article, and the light thrown upon the manufacture of glass in general by the accurate means now possessed of purifying its several ingredients, would have brought the art long since to the highest state of perfection in this country, but for the long continued vexatious interference and obstructions of our excise laws now happily at an end.

The researches of Berzelius having removed all doubts concerning the acid character of silica, the general composition of glass presents now no difficulty of conception. This substance consists of one or more salts, which are silicates with bases of potash, soda, lime, oxide of iron, alumina, or oxide of lead; in any of which compounds we can substitute one of these bases for another, provided that one alkaline base be left. Silica in its turn may be replaced by the boracid acid, without causing the glass to lose its principal characters.

Under the title glass are therefore comprehended various substances fusible at a high temperature, solid at ordinary temperatures, brilliant, generally more or less transparent, and always brittle. The following chemical distribution of glasses has been proposed: —

1. Soluble glass; a simple silicate of potash or soda; or of both these alkalies.
2. Crown glass; silicate of potash and lime.
3. Bottle glass; silicate of soda, lime, alumina, and iron.
4. Common window glass; silicate of soda and lime; sometimes also of potash.
5. Plate glass; silica, soda or potash, lime, and alumina.
6. Ordinary crystal glass; silicate of potash and lead.
7. Flint glass; silicate of potash and lead; richer in lead than the preceding.
8. Strass; silicate of potash and lead; still richer in lead.
9. Enamel; silicate and stannate or antimoniate of potash or soda, and lead.

The following analyses of these varieties of glass will place the composition more completely before the reader: —

	Silicic Acid.	Potash or Soda.	Lime.	Oxide of Lead.	Alumina.	Water.
1. Soluble glass - -	62	26	0	0	0	12
2. Crown glass - -	63	22	12	0	3	0
3. Bottle glass - -	54	5	20	6 *ox. iron*	0	0
4. Window glass - -	69	11 *soda*	13	0	7	0
5. Plate glass - -	72	17 *soda*	6	2 *ox. iron*	2	0
6. Crystal - - -	61	6	0	33	0	0
7. Flint glass - -	45	12	0	43	0	0
8. Strap - - -	38	8	0	53	1	0
9. Enamel - - -	31	8	0	50	10 *ox. tin*	0

Bohemian glass has not been named among the varieties. It has been generally grouped with the English glass as containing no lead, but it has some special peculiarities, as the following analyses by Peligot will show: —

	Silica.	Potash.	Lime.	Alumina.	Soda.
Bohemian glass - -	76·0	15·0	8·0	1·0	0
Do. opal glass -	80·9	17·6	·7	·8	0
Do. mirror glass -	67·7	21·0	9·9	1·4	0
Do. hard glass (as analysed by Mr. Rowney)	73·0	11·5	10·5	2·0	3

In the following table is also given the analyses of a certain number of Bohemian glasses, which will indicate their composition with precision, and show how uncertain their composition is.

	(1.)	(2.)	(3.)	(4.)	(5.)	(6.)	(7.)	(8.)
Silica	71·6	71·7	69·4	62·8	75·9	78·85	70·	57·
Potassa	11·0	12·7	11·8	22·1	- -	5·5	20·	25·
Soda	- -	2·3	- -	- -	17·5	12·05		
Lime	10·	10·3	9·2	12·5	3·8	5·6	4·	12·5
Magnesia	2·3							
Alumina	2·2	0·4	9·6	2·6	2·8	3·5	5·	3·
Oxide of Iron	3·9	0·3	- -	- -	- -	- -	0·6	1·3
Oxide of Manganese	0·2	0·2	- -	- -	- -	- -	0·4	0·4
	101·2	98·1	100·	100·	100·	100·5	100·	99·2

(1.) Bohemian glass from Neufeld (M. Grus).
(2.) A fine table glass from Neuwelt (M. Berthier); it is exceedingly beautiful, and is prepared, according to M. Perdonnet, with a mixture of 100 quartz, 50 caustic lime, 75 carbonate of potassa, and a very small quantity of nitre, arsenious acid, and oxide of manganese.
(3.) Old Bohemian glass (M. Dumas).
(4.) Crown glass of German manufacture (M. Dumas).
(5.) Glass for mirrors (M. Dumas).
(6.) Another glass for mirrors (M. Dumas).
(7.) White table glass, from Silberberg near Gratzen.
(8.) Mirror glass from New-Hurkenthal, for the manufacture of cast mirrors.

Peligot gives the analysis of Venetian aventurine as follows: —

Silica	67·7	Oxide of Tin	2·3
Potash	5·5	Oxide of Lead	1·1
Lime	8·9	Metallic Copper	3·9
Soda	7·1	Oxide of Iron	3·5

See AVENTURINE.

The following analyses of different varieties of continental glass are instructive :—

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
Silica	71·7	69·2	62·8	60·4	53·55	42·5
Potash	12·7	15·8	22·1	3·2	5·48	11·7
Soda	2·5	3·0	- -	S. pot.		
Lime	10·3	7·6	1 5	20·7	29·22	0·5
Alumina	0·4	1·2		10·4	6·01	1·8
Magnesia	- -	2·0	2·6	0·6		
Oxide of iron	0·3	0·5		3·8	5·74	
— manganese	0·2					
— lead	- -	- -	- -	- -	- -	43·5
Baryta	- -	- -	- -	0·9		

No. 1. is a very beautiful white wine glass of Neuwelt in Bohemia.
No. 2. Glass tubes, much more fusible than common wine glasses.
No. 3. Crown glass of Bohemia.
No. 4. Flask glass of St. Etienne, for which some heavy spar is used.
No. 5. Glass of Sevres.
No. 6. Guinand's flint glass.

Ancient glass has the following composition; the analyses are by Richard Phillips: —

	Silica.	Alumina.	Oxide of Iron.	Manganese.	Lime.	Magnesia.	Soda.
Roman base	70·58	1·80	0·53	0·48	8·00	trace	18·86
Do. Flatted glass	71·95	trace	3·45	0·57	7·33	0·60	15·30
Do. Lachrymatory	71·45	2·15	1·02	·17	8·14	trace	16·62

Thus we see that the ancient glasses were all soda glasses.
The glasses which contain several bases are liable to suffer different changes when

they are melted or cooled slowly. The silica is divided among these bases, forming new compounds in definite proportions, which by crystallising separate from each other, so that the general mixture of the ingredients which constitute the glass is destroyed. It becomes then very hard, fibrous, opaque, much less fusible, a better conductor of electricity and of heat; forming what Reaumur styled *devitrified* glass; and what is called after him Reaumur's porcelain.

This altered glass can always be produced in a more or less perfect state, by melting the glass and allowing it to cool very slowly; or merely by heating it to the softening pitch, and keeping it at that heat for some time. The process succeeds best with the most complex vitreous compounds, such as bottle glass; next with ordinary window glass; and lastly with glass of potash and lead.

This property ought to be kept constantly in view in manufacturing glass. It shows why in making bottles we should fashion them as quickly as possible with the aid of a mould, and reheat them as seldom as may be absolutely necessary. If glass is often heated and cooled, it loses its ductility, becomes refractory, and exhibits a multitude of stony granulations throughout its substance. When coarse glass is worked at the enameller's lamp, it is apt to change its nature in the same way, if the workman be not quick and expert at his business.

Fusibility, Cooling, Annealing, Devitrification. — All glass is more or less fusible; when it is softened by the action of heat, it may be worked with the greatest ease, and may be drawn out into threads as fine as those of the cocoon of the silkworm. Glass, when it is submitted to rapid cooling, becomes very fragile, and presents several very remarkable phenomena, among which as an example Prince Rupert's drops may be instanced. Glass supports variations of temperatures better in proportion as it has been more slowly cooled; thus, when it has been slightly annealed, or not at all, its fragility may be considerably diminished by annealing it in water, or better, in boiling oil.

Action of Atmospheric and Chemical Agents. — The harder and more infusible a glass is, the less it is alterable by the action of atmospheric and chemical agents, with the exception of hydrofluoric acid. Glass which is too alkaline attracts gradually the moisture of the air, and loses its lustre and polish. Many glasses are perceptibly attacked by a prolonged boiling with water, and *à fortiori* by acid and alkaline solutions; thus, the bottle glass is frequently attacked by the tartar which is found in the wine. According to Guyton-Morveau, all glass which is attacked by prolonged boiling with concentrated solutions of alum, common salt, sulphuric acid, or potassa, is of bad quality.

From these facts we perceive the importance of making a careful choice of the glass intended to be worked in considerable masses, such as the large object glasses of telescopes; as their annealing requires a very slow process of refrigeration, which is apt to cause devitrified specks and clouds. For such purposes, therefore, no other species of glass is well adapted except that with bases of potash and lead; or that with bases of potash and lime. These two form the best flint glass and crown glass; and they should be exclusively employed for the construction of the object glasses of achromatic telescopes.

Glass, it will be apparent from the analyses given, may be defined in technical phraseology, to be a transparent homogeneous compound formed by the fusion of silica with oxides of the alkaline, earthy, or common metals. It is usually colourless, and then resembles rock crystal, but is occasionally stained by accident or design with coloured metallic oxides. At common temperatures it is hard and brittle, in thick pieces; in thin plates or threads, flexible and elastic; sonorous when struck; fracture conchoidal, and of that peculiar lustre called vitreous; at a red heat, becoming soft, ductile and plastic. Other bodies are capable of entering into vitreous fusion, as phosphoric acid, boracic acid, arsenic acid, as also certain metallic oxides, as of lead and antimony, and several chlorides; some of which are denominated glasses.

Silica, formerly styled the earth of flints, which constitutes the basis of all commercial glass, is infusible by itself in the strongest fire of our furnaces; but its vitreous fusion is easily effected by a competent addition of potash or soda, either alone or mixed with lime or litharge. The silica, which may be regarded as belonging to the class of acids, combines at the heat of fusion with these bases, into saline compounds; and hence glass may be viewed as a silicate of certain oxides, in which the acid and the bases exist in equivalent proportions. Were these proportions, or the quantities of the bases which silica requires for its saturation at the melting point, exactly ascertained, we might readily determine beforehand the best proportions of materials for the glass manufacture. But as this is far from being the case, and as it is, moreover, not improbable that the capacity of saturation of the silica varies with the temperature, and that the properties of glass also vary with the bases, we must in the present state of our knowledge, regulate the

proportions rather by practice than by theory, though the latter may throw an indirect light upon the subject. For example, a good colourless glass has been found by analysis to consist of 72 parts of silica, 13 parts of potash, and 10 parts of lime, in 95 parts. If we reduce these numbers to the equivalent ratios, we shall have the following results, taking the atomic weights as given by Berzelius:—

1 atom	potash =	590	14·67	
1	lime	356	8·84	
3	silica	1722	42·79	71·49
2	silica	1155	28·70	
		3823	95·00	

This glass would therefore have been properly better compounded with the just atomic proportions, to which it nearly approaches, viz. 71·49 silica, 14·67 potash, and 8·84 lime, instead of those given above as its actual constituents.

The proportions in which silica unites with the alkaline and other oxides are modified by the temperature as above stated; the lower the heat, the less silica will enter into the glass, and the more of the base will in general be required. If a glass which contains an excess of alkali be exposed to a much higher temperature than that of its formation, a portion of the base will be set free to act upon the materials of the earthen pot, or to be dissipated in fumes, until such a silicate remains as to constitute a permanent glass corresponding to that temperature. Hence the same mixture of vitrifiable materials will yield very different results, according to the heats in which it is fused and worked in the glasshouse; and therefore the composition should always be referrible to "the going" of the furnace. When a species of glass, which at a high temperature formed a transparent combination with a considerable quantity of lime, is kept for some time in fusion at a lower temperature, a portion of the lime unites with the silica into another combination of a semi-vitreous or even of a stony aspect, so as to spoil the transparency of the glass altogether. There is probably a supersilicate, and a sub-silicate formed in such cases; the latter being much the more fusible of the two compounds. The Reaumur's porcelain already mentioned, is an example of this species of vitreous change in which new affinities are exercised at a lower temperature. An excess of silica, caused by the volatilisation of alkaline matter with too strong firing, will bring on similar appearances.

The specific gravity of glass varies from 2·3 to 3·6. That of least specific gravity consists of merely silica and potash fused together; that with lime is somewhat denser, and with oxide of lead denser still. Plate glass made from silica, soda, and lime, has a specific gravity which varies from 2·5 to 2·6; crystal or flint glass containing lead from 3·0 to 3·6.

The density of several glasses *without lead* is as follows:—

Old Bohemian glass (Dumas)	2·396
Bohemian bottle glass	3·782
do. window glass	2·642
Fine glass, called Bohemian crystal	2·892
Mirror glass of Cherbourg (Dumas)	2·506
do. St. Gobain	2·488
do. Newhaus, 1812 (Scholz)	2·551
do. do. 1830	2·653

The power of glass to resist the action of water, alkalies, acids, air, and light, is in general the greater the higher the temperature employed in its manufacture, the smaller the proportion of its fluxes, and the more exact the equivalent ratios of its constituents. When glass contains too much alkali, it is partially soluble in water. Most crystal glass is affected by having water boiled in it for a considerable time; but crown glass being poorer in alkali, and containing no lead, resists that action much longer, and is therefore better adapted to chemical operations. In general also potash glass is more apt to become damp than soda glass, agreeably to the respective hygrometric properties of these two alkalies, and also to the smaller proportion of soda than of potash requisite to form glass.

Air and light operate upon glass probably by their oxidising property. Bluish or greenish coloured glasses become by exposure colourless, in consequence undoubtedly of the peroxidisement of the iron, to whose protoxide they owed their tint; other glasses become purple red from the peroxidisement of the manganese. The glasses which contain lead, suffer another kind of change in the air, if sulphuretted hydrogen be present; the oxide of lead is converted into a sulphuret, with the effect of rendering the surface of the glass opaque and iridescent. The more lead is in the glass, the quicker does this iridescence supervene. By boiling concentrated sulphuric acid in a glass

vessel, or upon glass, we can ascertain its power of resisting ordinary menstrua. Good glass will remain smooth and transparent; bad glass will become rough and dim. The conditions of decomposition as it occurs in glass of great age, have not been satisfactorily explained; the glass of the Roman tombs decomposes from the surface, exfoliating in a remarkable manner, film after film, of a pearly and beautifully iridescent character, falling off one after the other. The same kind of change is seen on the windows of our ancient churches.

The brittleness of unannealed glass by change of temperature is sometimes very great. This defect may be corrected by slowly heating the vessel in salt-water or oil to the highest pitch consistent with the nature of these liquids, and letting it cool very slowly. Within the limits of that range of heat, it will, in consequence of this treatment, bear alternations of temperature without cracking.

It has been said that glass made from silica and alkalies alone, will not resist the action of water, but that the addition of a little lime is necessary for this effect. In general 100 parts of quartzose sand require 33 parts of dry carbonate of soda for their vitrification, and 45 parts of dry carbonate of potash. But to make unchangeable alkaline glass especially with potash, a smaller quantity of this than the above should be used with a very violent heat. A small proportion of lime increases the density, hardness, and lustre of glass; and it aids in decomposing the alkaline sulphates and muriates always present in the pearlash of commerce. From 7 to 20 parts of dry slaked lime have been added for 100 of silica, with advantage, it is said, in some German glass manufactories, where the alkaline matter is soda; for potash does not assimilate well with the calcareous earth.

In many glass works on the continent, sulphate of soda is the form under which alkaline matter is introduced into glass. This salt requires the addition of 8 per cent. of charcoal to decompose and dissipate its acid; a result which takes place at a high heat, without the addition of any lime. 88 pounds of quartz-sand, 44 pounds of dry glauber salt, and 3 pounds of charcoal, properly mixed and fused, afford a limpid, fluent, and workable glass; with the addition of 17 pounds of lime, these materials fuse more readily into a plastic mass. If less carbon be added, the fusion becomes more tedious.

By a proper addition of galena (the native sulphuret of lead) to glauber salt and quartz sand, without charcoal, it is said a tolerably good crystal glass may be formed. The sulphuric acid of the salt is probably converted by the reaction of the sulphuret of lead into sulphurous acid gas, which is disengaged.

One atom of sulphuret of lead = 1495·67, is requisite to decompose 3 atoms of sulphate of soda = 2676. It is stated, on good authority, that a good colourless glass may be obtained by using glauber salt without charcoal, as by the following formula.

Quartz sand - - -	100 pounds	Lime - - - -	20 pounds
Calcined glauber salt -	20 „	Cullet of soda glass -	12 „

The melting heat must be continued for 26½ hours. A small quantity of the sand is reserved to be thrown in towards the conclusion of the process, in order to facilitate the expulsion of air bubbles. The above mixture will bear to be blanched by the addition of manganese and arsenic. The decomposition of the salt is in this case effected by the lime, with which the sulphuric acid first combines, which is then converted into sulphurous acid, and dissipated. Glass made in this way was found by analysis to consist of 79 parts of silica, 12 lime, and 9·6 soda, without any trace of gypsum or sulphuric acid.

Glauber salt is partially volatilised by the heat of the furnace, and acts upon the arch of the oven and the tops of the pots. This is best prevented by introducing at first into the pots the whole of the salt mixed with the charcoal, the lime, and one-fourth part of the sand; fusing this mixture at a moderate heat, and adding gradually afterwards the remainder of the sand, increasing the temperature at the same time. If we put in the whole ingredients together, as is done with potash glass, the sand and lime soon fall to the bottom, while the salt rises to the surface, and the combination becomes difficult and unequal.

Sulphate of potash acts in the same way as sulphate of soda.

Muriate of soda also, according to Kirn, may be used as a glass flux with advantage. The most suitable proportions are 4 parts of potash, 2 of common salt, and 3 of lime, agreeably to the following compositions.

	1.	2.
Quartz sand - - - -	60·0	57·1
Calcined carbonate of potash -	17·8	19·1
Common salt - - - -	8·9	9·5
Lime - - - - -	13·3	14·3

For No. 1, the melting heat must be 10 hours, which turns out a very pure, solid, good glass; for No. 2, 23 hours of the furnace are required. Instead of the potash, glauber salt may be substituted; the proportions being then 19·1 glauber salt, 9·5 muriate of soda, 14·3 lime, 57·1 sand, and 1·3 charcoal.

The oxide of lead is an essential constituent of the denser glasses, and may be regarded as replacing the lime, so as to form with the quartz-sand a silicate of lead. It assimilates best with purified pearlash, on account of the freedom of this alkali from iron, which is present in most sodas.

Its atomic constitution may be represented as follows:—

				Computation.	Analysis.
Silicic acid - - -	5 atoms	=	2877·0	59·19	59·20
Oxide of lead - - -	1	=	1394·5	28·68	28·20
Potash - - - -	1	=	590·0	12·13	9·00
Oxides of iron and manganese			- -	- -	1·40
			4861·5	100·00	97·80

The above analysis by Berthier relates to a specimen of the best English crystal glass, perfectly colourless and free from air-bubbles. This kind of glass may, however, take several different proportions of potash and silica to the oxide of lead.

The composition of mirror-plate, as made on the Continent, is as follows:—

White quartz-sand - - - - - -	300 pounds
Dry carbonate of soda - - - - -	100
Lime slaked in the air - - - - -	43
Cullet, or old glass - - - - -	300

The manganese should not exceed one half per cent. of the weight of soda.

Optical glass requires to be made with very peculiar care. It is of two different kinds; namely, *crown glass* and *flint glass*. The latter contains a considerable proportion of lead, in order to give it an increased dispersive power upon the rays of light, in proportion to its mean refractive power.

Optical crown glass should be perfectly limpid, and have so little colour, that a pretty thick piece of it may give no appreciable tinge to the rays of light. It should be exempt from striæ or veins as well as air-bubbles, and have not the slightest degree of milkiness. It should, moreover, preserve these qualities when worked in considerable quantities. Potash is preferable to soda for making optical crown glass, because the latter alkali is apt to make a glass which devitrifies and becomes opalescent, by long exposure to heat in the annealing process. A simple potash silicate would be free from this defect, but it would be too attractive of moisture, and apt to decompose eventually by the humidity of the atmosphere. It should, therefore, contain a small quantity of lime, and as little potash as suffices for making a perfect glass at a pretty high temperature. It is probably owing to the high heats used in the English crown glass works, and the moderate quantity of alkali (soda) which is employed, that our crown glass has been found to answer so well for optical purposes.

The following recipe for crown glass is excellent:—

5 atoms of silica ($2\frac{1}{2}$?) - - - - -	80
1 carbonate of soda - - - - -	54
5 silica - - - - - - -	80
1 carbonate of lime - - - - -	50
1 atom of carbonate of baryta - - -	98
5 atoms of silica - - - - - -	80

Silicates of lime and baryta *per se*, or even combined, are very refractory; but they vitrify well along with a third silicate, such as that of soda or potash.

The following are additional recipes for making different kinds of glass.

1. *Bottle glass.*—11 pounds of dry glauber salts; 12 pounds of soaper salts: a half bushel of waste soap ashes; 56 pounds of sand; 22 pounds of glass skimmings; 1 cwt. of green broken glass; 25 pounds of basalt. This mixture affords a dark green glass.

2. Yellow or white sand, 100 parts; kelp, 30 to 40; lixiviated wood ashes, from 160 to 170 parts; fresh wood ashes, 30 to 40 parts; potter's clay, 80 to 100 parts; cullet or broken glass, 100. If basalt be used, the proportion of kelp may be diminished.

In two bottle-glass houses in the neighbourhood of Valenciennes, an unknown in-

gredient, sold by a Belgian, was employed, which he called *spar*. This was discovered by chemical analysis to be sulphate of baryta. The glass-makers observed that the bottles which contained some of this substance were denser, more homogeneous, more fusible, and worked more kindly, than those formed of the common materials. When one prime equivalent of the silicate of baryta = 123, is mixed with three primes of the silicate of soda = (3 × 77·6) 232·8, and exposed in a proper furnace, vitrification readily ensues, and the glass may be worked a little under a cherry-red heat, with as much ease as a glass of lead, and has nearly the same lustre.

3. *Green window glass, or broad glass.*—11 pounds of dry glauber salt; 10 pounds of soaper salts; half a bushel of lixiviated soap waste; 50 pounds of sand; 22 pounds of glass pot skimmings; 1 cwt. of broken green glass.

4. *Crown glass.*—300 parts of fine sand; 200 of good soda ash; 33 of lime; from 250 to 300 of broken glass; 60 of white sand; 30 of purified potash; 15 of saltpetre (1 of borax); ½ of arsenious acid.

5. *Nearly white table glass.*—20 pounds of potashes; 11 pounds of dry glauber salts; 16 of soaper salt; 55 of sand; 140 of cullet of the same kind. Another. — 100 of sand; 235 of kelp; 60 of wood ashes; 1½ of manganese; 100 of broken glass.

6. *White table glass.*—40 pounds of potashes; 11 of chalk; 76 of sand; ½ of manganese; 95 of white cullet.

Another.—50 of purified potashes; 100 of sand; 20 of chalk; and 2 of saltpetre.

Bohemian table or plate glass is made with 63 parts of quartz; 26 of purified potashes; 11 of sifted slaked lime, and some cullet.

7. *Crystal glass.*—60 parts of purified potashes; 120 of sand; 24 of chalk; 2 of saltpetre; 2 of arsenious acid; ⅛ of manganese.

Another.—70 of purified pearl ashes; 120 of white sand; 10 of saltpetre; ½ of arsenious acid; ¼ of manganese.

A third.—67 of sand; 23 of purified pearl ashes: 10 of sifted slaked lime; ¼ of manganese; (5 to 8 of red lead).

A fourth.—120 of white sand; 50 of red lead; 40 of purified pearl ashes; 20 of saltpetre; ¼ of manganese.

A fifth.—120 of white sand; 40 of pearl ashes purified; 35 of red lead; 13 of saltpetre; ⅛ of manganese.

A sixth.—30 of the finest sand; 20 of red lead; 8 of pearl ashes purified; 2 of saltpetre; a little arsenious acid and manganese.

A seventh.—100 of sand; 45 of red lead; 35 of purified pearl ashes; ¼ of manganese; ½ of arsenious acid.

8. *Plate glass.*—Very white sand, 300 parts; dry purified soda, 100 parts; carbonate of lime, 43 parts; manganese, 1; cullet, 300.

Another.—Finest sand, 720; purified soda, 450; quicklime, 80 parts; saltpetre, 25 parts; cullet, 425.

A little borax has also been prescribed; much of it communicates an exfoliating property to glass.

Practical Details of the Manufacture of Glass.

There are five different species of glass, each requiring a peculiar mode of fabrication, and peculiar materials:—1. The coarsest and simplest form of this manufacture is *bottle* glass. 2. Next to it in cheapness of material may be ranked *broad* or *spread window glass*. An improved article of this kind is now made near Birmingham, under the name of British or German plate. 3. Crown glass comes next, or window glass, formed in large circular plates or discs. This glass is peculiar to Great Britain. 4. Flint glass, crystal glass, or glass of lead. 5. Plate or fine mirror glass.

The Pots.—The materials of every kind of glass are vitrified in pots made of a pure refractory clay; the best kind of which is a species of shale or slate clay dug out of the coal-formation near Stourbridge. It contains hardly any lime or iron, and consists of silica and alumina in nearly equal proportions. The masses are carefully picked, brushed, and ground under edge iron wheels of considerable weight, and sifted through sieves having 20 meshes in the square inch. This powder is moistened with water (best hot), and kneaded by the feet or a loam-mill into an uniform smooth paste. A large body of this dough should be made up at a time, and laid by in a damp cellar to ripen. Previously to working it into shapes, it should be mixed with about a fourth of its weight of cement of old pots, ground to powder. This mixture is sufficiently plastic, and being less contractile by heat, forms more solid and durable vessels. Glass-house pots have the figure of a truncated cone, with the narrow end undermost; those for bottle and window-glass being open at top, about 30 inches diameter at bottom, 40 inches at the mouth, and 40 inches deep; but the flint-glass pots are covered in at top with a dome-cap, having a mouth at the side, by which the

materials are introduced, and the glass is extracted. Bottle and crown-house pots are from 3 to 4 inches thick; those for flint-houses are an inch thinner, and of proportionally smaller capacity. See CLAY.

The well-mixed and kneaded dough is first worked upon a board into a cake for the bottom; over this the sides are raised, by laying on its edges rolls of clay above each other with much manual labour, and careful condensation. The clay is made into lumps, is equalised, and slapped much in the same way as for making pottery. The pots thus fashioned must be dried very prudently, first in the atmospheric temperature, and finally in a stove floor, which usually borrows its heat directly from the glass-house. Before *setting the pots* in the furnace, they are annealed during 4 or 5 days, at a red heat in a small reverberatory vault, made on purpose. When completely annealed, they are transferred with the utmost expedition into their seat in the fire, by means of powerful tongs supported on the axle of an iron-wheel carriage frame, and terminating in a long lever for raising them and swinging them round. The *pot-setting* is a desperate service, and when unskilfully conducted without due mechanical aids, is the forlorn hope of the glass-founder.

The glass-houses are usually built in the form of a cone, from 60 to 100 feet high, and from 50 to 80 feet in diameter at the base. The furnace is constructed in the centre of the area, above an arched or groined gallery which extends across the whole space, and terminates without the walls, in large folding doors. This cavern must be sufficiently high to allow labourers to wheel out the cinders in their barrows, The middle of the vaulted top is left open in the building, and is covered over with the grate-bars of the furnace.

1. *Bottle glass.* — The bottle-house and its furnace resemble nearly *fig.* 895. The furnace is usually an oblong square chamber, built of large fire-bricks, and arched over with fire-stone, a siliceous grit of excellent quality extracted from the coal measures of Newcastle. This furnace stands in the middle of the area; and has its base divided into three compartments. The central space is occupied by the grate-bars: and on either side is the platform or fire-brick *siege* (seat), raised about 12 inches above the level of the ribs upon which the pots rest. Each *siege* is about 3 feet broad.

In the sides of the furnace semi-circular holes of about a foot diameter are left, opposite to, and a little above the top of, each pot, called working holes, by which the workmen shovel in the materials, and take out the plastic glass. At each angle of the furnace there is likewise a hole of about the same size, which communicates with the calcining furnace of a cylindrical form, dome-shaped at top. The flame that escapes from the founding or pot-furnace is thus economically brought to reverberate on the raw materials of the bottle glass, so as to dissipate their carbonaceous or volatile impurities, and convert them into a frit. A bottle-house has generally eight other furnaces or fire arches; of which six are used for annealing the bottles after they are blown, and two for annealing the pots, before setting them in the furnace.

Generally, for common bottles, the common river sand and soap-boilers' waste are used. About 3 parts of waste, consisting of the insoluble residuum of kelp mixed with lime, and a little saline substance, are employed for 1 part of sand. This waste is first of all calcined in two of the fire arches or reverberatories reserved for that purpose, called the coarse arches, where it is kept at a red heat, with occasional stirring, from 24 to 30 hours, being the period of a journey, or *journée*, in which the materials could be melted and worked into bottles. The roasted soap-waste is then withdrawn under of the name of ashes, from its arch, coarsely ground, and mixed with its proper proportion of sand. This mixture is now put into the fine arch, and calcined during the working journey, which extends to 10 or 12 hours. Whenever the pots are worked out, that frit is immediately transferred into them in its ignited state, and the founding process proceeds with such despatch that this first charge of materials is completely melted down in 6 hours, so that the pots might admit to be filled up again with the second charge of frit, which is founded in 4 hours more. The heat is briskly continued, and in the course of from 12 to 18 hours, according to the size of the pots, the quality of the fuel, and the draught of the furnace, the vitrification is complete. Before blowing the bottles, however, the glass must be left to settle, and to cool down to the blowing consistency, by shutting the *cave* doors and feeding holes, so as to exclude the air from the fire-grate and the bottom of the hearth. The glass or metal becomes more dense, and by its subsidence throws up the foreign lighter earthy and saline matters in the form of a scum on the surface, which is removed with skimming irons. The furnace is now charged with coal, to enable it to afford a working heat for 4 or 5 hours, at the end of which time more fuel is cautiously added to preserve adequate heat for finishing the *journey*.

It is hardly possible to convey in words alone a correct idea of the manipulations necessary to the formation of a wine bottle. Six people are employed at this task;

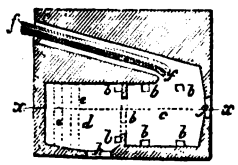
one, called a gatherer, dips the end of an iron tube, about five feet long, previously made red hot, into the pot of melted *metal*, turns the rod round so as to surround it with glass, lifts it out to cool a little, and then dips and turns it round again; and so in succession till a ball is formed on its end sufficient to make the required bottle. He then hands it to the blower, who rolls the plastic lump of glass on a smooth stone or cast-iron plate, till he brings it to the very end of the tube; he next introduces the pear-shaped ball into an open brass or cast-iron mould, shuts this together by pressing a pedal with his foot, and holding his tube vertically, blows through it, so as to expand the cooling glass into the form of the mould. Whenever he takes his foot from the pedal-lever, the mould spontaneously opens out into two halves, and falls asunder by its bottom hinge. He then lifts the bottle up at the end of the rod, and transfers it to the finisher, who, touching the glass-tube at the end of the pipe with a cold iron, cracks off the bottle smoothly at its mouth-ring. The finished bottles are immediately piled up in the hot annealing arch, where they are afterwards allowed to cool slowly for 24 hours at least.

2. *Broad or spread window glass.*—This kind of glass is called *inferior* window glass in this country, because coarse in texture, of a wavy wrinkled surface, and very cheap; but on the continent *spread* window glass, being made with more care, is much better than ours, though still far inferior in transparency and polish to crown glass, which has, therefore, nearly superseded its use among us. But Messrs. Chance and Co., of Birmingham, make *British sheet glass* upon the best principles, and turn out an article quite equal, if not superior, to anything of the kind made either in France or Belgium. Their materials are those used in the crown-glass manufacture. The vitrifying mixture is fritted for 20 or 30 hours in a reverberatory arch, with considerable stirring and puddling with long-handled shovels and rakes; and the frit is then transferred by shovels, while red hot, to the melting pots to be founded. When the glass is rightly vitrified, settled, and brought to a working heat, it is lifted out by iron tubes, blown into pears, which, being elongated into cylinders, are cracked up along one side parallel to the axis, by touching them with a cold iron dipped in water, and are then opened out into sheets. The glass cylinders are spread on a bed of smooth stone Paris-plaster, or laid on the bottom of a reverberatory arch; the cylinder being placed on its side horizontally, with the cracked line uppermost, gradually opens out, and flattens on the hearth. At one time, thick plates were thus prepared for subsequent polishing into mirrors; but the glass was never of very good quality; and this mode of making mirror-plate has accordingly been generally abandoned.

The spreading furnace or oven is that in which cylinders are expanded into tables or plates. It ought to be maintained at a brisk red heat, to facilitate the softening of the glass. The oven is placed in immediate connection with the annealing arch, so that the tables may be readily and safely transferred from the former to the latter. Sometimes the cylinders are spread in a large muffle furnace, in order to protect them from being tarnished by sulphureous and carbonaceous fumes.

Fig. 890 represents a ground plan of both the spreading and annealing furnace; *fig.* 891 is an oblong profile in the direction of the dotted line *x x*, *fig.* 890.

890



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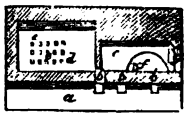
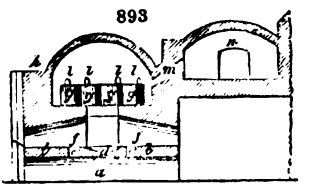


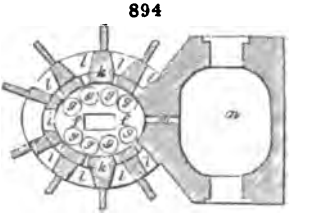
a is the fire-place; *b b*, the canals or flues through which the flame rises into both furnaces; *c*, the spreading furnace, upon whose sole is the spreading slab. *d*, is the cooling and annealing oven; *e e*, iron bars which extend obliquely across the annealing arch, and serve for resting the glass tables against during the cooling. *f f*, the channel along which the previously cracked cylinders are slid, so as to be gradually warmed; *g*, the opening in the spreading furnace, for enabling the workmen to regulate the process; *h*, a door in the annealing arch, for introducing the tools requisite for raising up and removing the tables.

The series of transformations in sheet glass, already described, is represented in *fig.* 892, at A, B, C, D, E, F, G, H.

Figs. 893 and 894 represent a Bohemian furnace in which excellent white window glass is founded. *Fig.* 893 is a longitudinal section of the glass and annealing furnace. *Fig.* 894 is the ground plan. *a* is the ash pit vaulted under the sole of the furnace;

the fire-place itself is divided into three compartments; with a middle slab at *d*, which is hollowed in the centre, for collecting any spilt glass, and two hearth tiles or slabs *b b*. *c c* are the draught or air holes; *e e* are arches upon which the bearing slabs *f f* partly rest. In the middle between these arches, the flame strikes upwards upon the pots *g g*, placed as closely together as possible for economy of room. *h* is the breast wall of the furnace; *i*, *fig.* 894, the opening through which the pots are introduced; it is bricked up as soon as they are set. *k k* is the base of the cone or dome of the furnace; *l l l*, the working orifices, which are made larger or smaller according to the size of the glass articles to be made. *m* is the flue which leads to the annealing stove *n*, with an arched door. Exterior to this there is usually a drying kiln, not shown in the figure; and there are adjoining stoves, called *arches*, for drying and annealing the new pots before they are set,

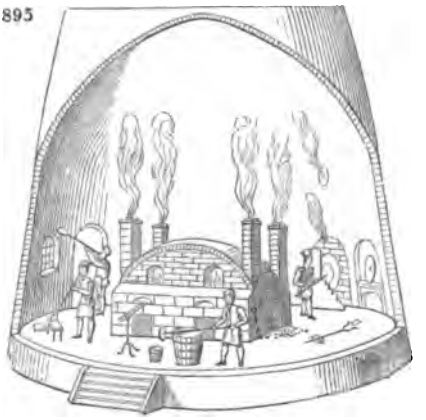




The cooling or annealing arch, or leer, is often built independent of the glass-house furnace, is then heated by a separate fire-place, and constructed like a very long reverberatory furnace.

The leer pans, or trays of sheet iron, are laid upon its bottom in an oblong series, and hooked to each other.

3. *Crown-glass.* — The crown-glass house with its furnace is represented in *fig.* 895, where the *blowing* operation is shown on the one side of the figure, and the *flashing* on the other. The furnace is usually constructed to receive 4 or 6 pots, of such dimensions as to make about a ton of glass each at a time. There are, however, several subsidiary furnaces to a crown-house: 1, a reverberatory furnace or *calcar*, for calcining or fritting the materials; 2, a blowing furnace, for blowing the pear-shaped balls made at the pot-holes, into large globes, 3, a flashing furnace, and bottoming hole for communicating a softening heat, in expanding the globe into a circular plate; 4, the annealing arch for the finished tables; 5, the reverberatory oven for annealing the pots prior to their being set upon the foundir g *siege*.



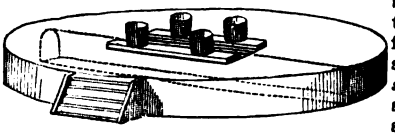
The materials of crown glass used to be, fine sand, by measure 5 parts, or by weight 10; ground kelp, by measure 11 parts, or by weight 16½; but instead of kelp, soda ash is now generally employed. From 6 to 8 cwt. of sand, lime, and soda-ash, mixed together in wooden boxes with a shovel, are thrown on the sole of a large reverberatory. Here the mixture is well worked together with iron paddles, flat shovels, and rakes with long handles; the area of this furnace being about 6 feet square, and the height 2 feet. The heat soon brings the materials to a pasty consistence, when they must be diligently turned over, to favour the dissipation of the carbon, sulphur, and other volatile matters of the kelp or soda ash, and to incorporate the fixed ingredients uniformly with the sand. Towards the end of 3 hours, the fire is considerably raised, and when the fourth hour has expired, the fritting operation is finished. The mass is now shovelled or raked out into shallow cast-iron square cases, smoothed down, and divided before it hardens by cooling, into square lumps, by cross sections with the spade. These frit-bricks are afterwards piled up

in a large apartment for use; and have been supposed to improve with age, by the efflorescence of their saline constituents into carbonate of soda on their surface.

The founding-pots are filled up with these blocks of frit, and the furnace is powerfully urged by opening all the subterranean passages to its grate, and closing all the doors and windows of the glass-house itself. After 8 or 10 hours the vitrification has made such progress, and the blocks first introduced are so far melted down, that another charge of frit can be thrown in, and thus the pot is fed with frit till the proper quantity is used. In about 16 hours the vitrification of the frit has taken place, and a considerable quantity, amounting often to the cwt. of liquid saline matter floats over the glass. This salt is carefully skimmed off into iron pots with long ladles. It is called Sandiver, or Glass-gall, and consists usually of muriate of soda, with a little sulphate. The pot is now ready for receiving the *topping of cullet*, which is broken pieces of window glass, to the amount of 3 or 4 cwt. This is shovelled in at short intervals; and as its pressure forces up the residuary saline matter, this is removed; for were it allowed to remain, the body of the glass would be materially deteriorated.

The heat is still continued for several hours till the glass is perfect, and the extrication of gas called the *boil*, which accompanies the fusion of crown glass, has nearly terminated, when the fire is abated, by shutting up the lower vault doors and every avenue to the grate, in order that the glass may settle fine. At the end of about 40 hours altogether, the fire being slightly raised by adding some coals, and opening the doors, the glass is carefully skimmed, and the working of the pots commences.

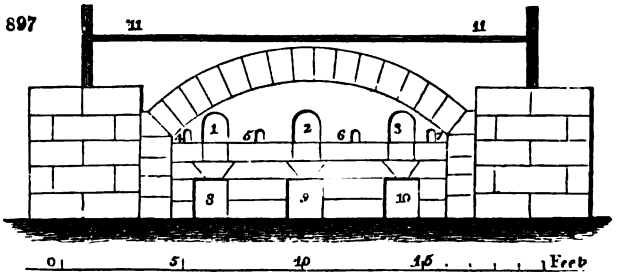
896



Before describing it, however, we may state that the marginal figure, 896, shows the base of the crown-house cone, with the four open pots in two ranges on opposite sides of the furnace, sitting on their raised *sieges*, at each side of the grate. At one side of the base the door of the vault is shown, and its course is marked by the dotted lines.

The crown-glass furnace, *figs.* 897, 898, is an oblong square, built in the centre of a brick cone, large enough to contain within it two or three pots at each side of the

897



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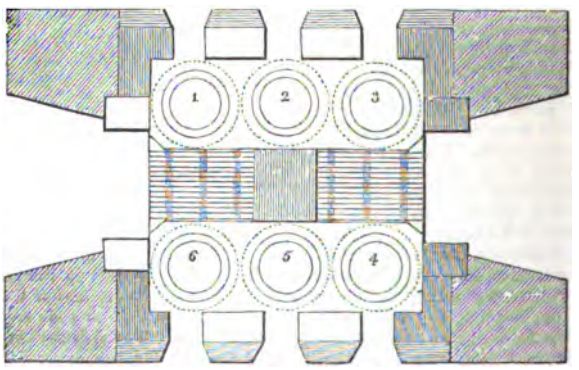


grate room, which is either divided as shown in the plan, or runs the whole length of the furnace, as the manufacturer chooses. *Fig.* 898 is a ground plan, and *fig.* 897 a

front elevation of a six-pot furnace. 1, 2, 3, *fig.* 897, are the working holes for the purposes of ventilation, of putting in the materials, and of taking out the metal to be wrought. 4, 5, 6, 7, are pipe holes for warming the pipes before beginning to work with them. 8, 9, 10, are foot holes for mending the pots and sieges. 11 is a bar of iron for binding the furnace, and keeping it from swelling.

The arch is of an elliptic form; though a barrel arch, that is, an arch shaped like the half of a barrel cut longwise through the centre, is sometimes used. But this soon gives way when used in the manufacture of crown glass, although it does very well in the clay-furnace used for bottle houses.

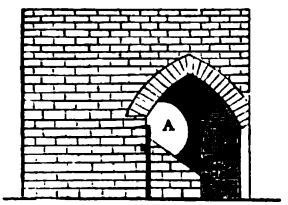
The best stone for building furnaces is fire-stone; it may be obtained in the neighbourhood of Newcastle from the coal-measures generally, and some of the sandstones of the eastern counties are found to answer the purpose admirably. The great danger in building furnaces is, lest the cement at the top should give way with the excessive heat, and by dropping into the pots, spoil the metal. The top should therefore be built with stones only, as loose as they can hold together after the centres are removed, and without any cement whatever. The stones expand and come quite close together when annealing; an operation which takes from eight to fourteen days at most. There is thus less risk of any thing dropping from the roof of the furnace.

The inside of the square of the furnace is built either of Stourbridge fire-clay annealed, or of fire-stone, to the thickness of sixteen inches. The outside is built of common brick, about nine inches in thickness.

The furnace is thrown over an ash-pit, or cave as it is called, which admits the atmospheric air, and promotes the combustion of the furnace. This cave is built of stone until it comes beneath the grate room, when it is formed of fire-brick. The abutments are useful for binding and keeping the furnace together, and are built of masonry. The furnaces are stoutly clasped with iron all round, to keep them tight. In four-pot furnaces this is unnecessary, provided there be four good abutments.

Fig. 899 is an elevation of the flashing furnace. The outside is built of common brick, the inside of fire-brick, and the mouth or nose of Stourbridge fire-clay.

899



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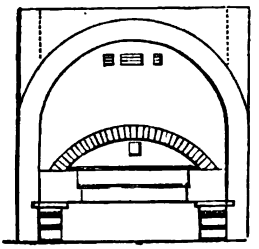

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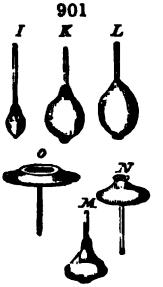


Fig. 900 is the annealing kiln. It is built of common brick, except round the grate room, where fire-brick is used.

Few tools are needed for blowing and flashing crown-glass. The requisite ball of plastic glass is gathered, in successive layers as for bottles, on the end of an iron tube, and rolled into a pear-shape, on a cast-iron plate; the workman taking care that the air blown into its cavity is surrounded with an equal body of glass, and if he perceives any side to be thicker than another, he corrects the inequality by rolling it on the sloping iron table called marver (marbre). He now heats the bulb in the fire, and rolls it so as to form the glass upon the end of the tube, and by a dexterous swing or two he lengthens it, as shown in I, *fig.* 901. To extend the neck of that pear, he next rolls it over a smooth iron rod, turned round in a horizontal direction, into the shape K, *fig.* 901. By further expansion at the blowing furnace, he now brings it to the shape L, represented in *fig.* 901.

This spheroid having become cool and somewhat stiff, is next carried to the bottoming hole (like *fig.* 899), to be exposed to the action of flame. A slight wall erected before one half of this hole, screens the workman from the heat, but leaves room for the globe to pass between it and the posterior wall. The blowing-pipe is made to rest a little way from the neck of the globe, on a hook fixed in the front wall; and thus may be made easily to revolve on its axis, and by giving centrifugal force to the globe, while the bottom of it, or part opposite to the pipe, is softened by the heat, it soon assumes the form exhibited in M, *fig.* 901.

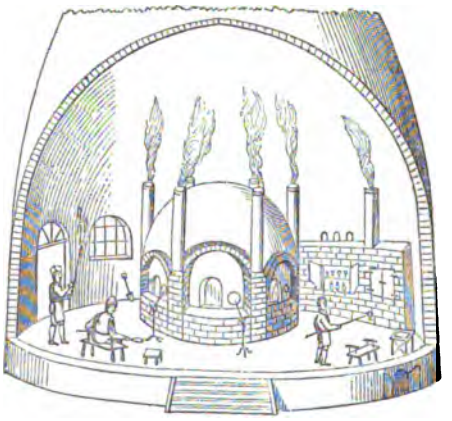
In this state the flattened globe is removed from the fire, and its rod being rested on the *casher box* covered with coal cinders, another workman now applies the end of

a solid iron rod tipped with melted glass, called a *punto*, to the nipple or prominence in the middle; and thus attaches it to the centre of the globe, while the first workman cracks off the globe by touching its tubular neck with an iron chisel dipped in cold water. The workman having thereby taken possession of the globe by its bottom or knobbled pole attached to his punty rod, he now carries it to another circular opening, where he exposes it to the action of moderate flame with regular rotation, and thus slowly heats the thick projecting remains of the former neck, and opens it slightly out, as shown at N, in *fig.* 901. He next hands it to the *flasher*, who, resting the iron rod in a hook placed near the side of the orifice A, *fig.* 899, wheels it rapidly round opposite to a powerful flame, till it assumes first the figure o, and finally that of a flat circular table.

The flasher then walks off with the table, keeping up a slight rotation as he moves along, and when it is sufficiently cool, he turns down his rod into a vertical position, and lays the table flat on a dry block of fire-clay, or bed of sand, when an assistant nips it off from the *punto* with a pair of long iron shears, or cracks it off with a touch of cold iron. The loose table or plate is lastly lifted up horizontally on a double pronged iron fork, introduced into the annealing arch, *fig.* 900, and raised on edge; an assistant with a long-kneed fork preventing it from falling too rapidly backwards. In this arch a great many tables of glass are piled up in iron frames, and slowly cooled from a heat of about 600° to 100° F., which takes about 24 hours; when they are removed. A circular plate or table of about 5 feet diameter weighs on an average 9 pounds.

4. *Flint glass.*—This kind of glass is so called because originally made with calcined flints, as the siliceous ingredient. The materials at present employed in this country for the finest flint glass are, first, sand, calcined, sifted, and washed; second, an oxide of lead, either red lead or litharge; and third, pearlash. Sand for flint glass manufacture is obtained from the Isle of Wight, Aylesbury, the New Forest, and some other localities in this country. A very beautiful sand is brought from America, and some has been sent home from Australia. The pearl ash of commerce must however be purified by digesting it in a very little hot water, which dissolves the carbonate of potash, and leaves the foreign salts, chiefly sulphate of potash, muriate of potash, and muriate of soda. The solution of the carbonate being allowed to cool and become clear in lead pans, is then run off into a shallow iron boiler, and evaporated to dryness. Nitre is generally added as a fourth ingredient of the body of the glass; and it serves to correct any imperfections which might arise from accidental combustible particles, or from the lead being not duly oxidised. The above four substances constitute the main articles; to which we may add arsenic and manganese, introduced in very small quantities, to purify the colour and clear up the transparency of the glass. The black oxide of manganese, when used in such quantity only as to peroxidise the iron of the sand, simply removes the green tinge caused by the protoxide of iron; but if more manganese be added than accomplishes that purpose, it will give a purple tinge to the glass. The arsenic is supposed to counteract the injury arising from excess of manganese, but is itself very apt on the other hand to communicate some degree of opalescence, or at least to impair the lustre of the glass.

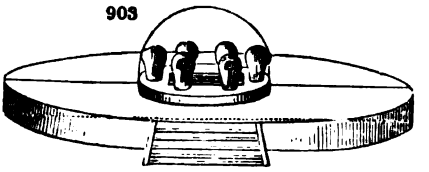
902



The raw materials of flint glass, are always mixed with about a third or a fourth of their weight of broken glass of like quality; this mixture is thrown into the pot with a shovel; and more is added whenever the preceding portions by melting subside; the object being to obtain a pot full of glass, to facilitate the skimming off the impurities and sandiver. The mouth of the pot is now shut, by applying clay-lute round the stopper, with the exception of a small orifice below, for the escape of the liquid saline matter. Flint glass requires about 48 hours for its complete vitrification, though the materials are more fusible than those of crown glass; in consequence of the contents of the pot being partially screened by its cover from the action of the fire, as also from the lower intensity of the heat.

Fig. 902 represents a flint glass house for 6 pots, with the arch or leer on one side for annealing the crystal ware. In *fig.* 903, the base of the cone is seen, and the glass pots *in situ* on their platform ranged round the central fire grate. The dotted line denotes the contour of the furnace, *fig.* 902.

903



Whenever the glass appears fine, and is freed from its air bubbles, which it usually is in about 36 hours, the heat is suffered to fall a little by closing the bottom valves, &c., that the pot may settle; but prior to working the metal, the heat is *somewhat raised* again.

It would be useless to describe the manual operations of fashioning the various articles of the flint-glass manufacture, because they are indefinitely varied to suit the conveniences and caprices of human society.

Every different flint-house has a peculiar proportion of glass materials. The following have been offered as good practical mixtures: —

1.	Fine white sand	300 parts.
	Red lead or litharge	200
	Refined pearl ashes	80
	Nitre	20
	Arsenic and manganese, a minute quantity.	
2.	Fine sand	50·5
	Litharge	27·2
	Refined pearl ashes (carbonate of potash, with 5 per cent. of water)	17·5
	Nitre	4·8
		100·0

To these quantities from 30 to 50 parts of broken glass or cullet are added, with about a two-thousandth part of manganese, and a three-thousandth part of arsenic. But manganese varies so extremely in its purity, and contains often so much oxide of iron, that nothing can be predicated as to its quantity previously to trial.

M. Payen, an eminent manufacturing chemist in France, says that the composition of "crystal" (the name given in France to their finest flint glass) does not deviate much from the following proportions :—

	Wood fire.	Coal fire.
Siliceous sand	3	3
Minium	2	2¼
Carbonate of potash	1½	1⅝

The flint-glass *leer* for annealing glass, is an arched gallery or large flue, about 36 feet long, 3 feet high, 4 wide; having its floor raised above 2 feet above the ground of the glass-house. The hot air and smoke of a fire-place at one end pass along this gallery, and are discharged by a chimney 8 or 10 feet short of the other end. On the floor of the vault, large iron trays are laid and hooked to each other in a series, which are drawn from the fire end towards the other by a chain, wound about a cylinder by a winch handle projecting through the side. The flint-glass articles are placed in their hot state into the tray next the fire, which is moved onwards to a cooler station whenever it is filled, and an empty tray is set in its place. Thus, in the course of about 20 hours, the glass advances to the cool end thoroughly annealed.

Besides colourless transparent glass, which forms the most important part of this manufacture, various coloured glasses are made to suit the taste of the public. The opaline crystal may be prepared by adding to the above composition (No. 2) phosphate of lime, or well burnt bone-ash in fine powder, washed, and dried. The article must be as uniform in thickness as possible, and speedily worked into shape, with a moderate heat. Oxide of tin, *putty-powder*, was formerly used for making opalescent glass, but the lustre of the body was always impaired by its means.

Crystal vessels are made of which the inner surface is colourless, and all the external facets coloured. Such works are easily executed. The end of the blowing-rod must be dipped first in the pot containing colourless glass, to form a bulb of a certain size, which being cooled a little is then dipped for an instant into the pot of coloured glass. The two layers are associated without intermixture; and when the article is finished in its form, it is white within and coloured without. Fluted lines somewhat deeply cut, pass through the coloured coat, and enter the colourless one; so that when they cross, their ends alone are coloured.

For some time past, likewise, various crystal articles have been exhibited in the

market with coloured enamel figures on their surface, or with white incrustations of a silvery lustre in their interior. The former are prepared by placing the enamel object in the brass mould, at the place where it is sought to be attached. The bulb of glass being put into the mould, and blown while very hot, the small plate of enamel gets cemented to the surface. For making the white argentine incrustations, small figures are prepared with an impalpable powder of dry porcelain paste, cemented into a solid by means of a little gypsum plaster. When these pieces are thoroughly dried, they are laid on the glass while it is red hot, and a large patch of very liquid glass is placed above it, so as to encase it and form one body with the whole. In this way the incrustation is completely enclosed; and the polished surface of the crystal which scarcely touches it, gives a brilliant aspect, pleasing to the eye.

Optical Glass. — An uniform flint-glass, free from striæ, or *wreath*, is much in demand for the optician. It would appear that such an article was much more commonly made by the English manufacturers many years ago, than at present; and that in improving the brilliancy of crystal glass they have injured its fitness for constructing optical lenses, which depends, not so much on its whiteness and lustre, as on its homogeneous character. Even a potful of pretty uniform glass, when it stands some time liquid, becomes eventually unequable by the subsidence of the denser portions; so that striæ and gelatinous appearances begin to manifest themselves, and the glass becomes of little value. Glass allowed to cool slowly in mass in the pot is particularly full of wreath, and if quickly refrigerated, that is in two or three hours, it is apt to split into a multitude of minute splinters, of which no use can be made. For optical purposes, the glass must be taken out in its liquid state, being gathered on the end of the iron rod from the central portion of a recently skimmed pot, after the upper layers have been worked off in general articles.

M. Guinand, of Brenets near Neufchatel, a workman in the watch and clock trade, appears to have discovered processes that furnished almost certainly pieces of flint glass capable of forming good lenses of remarkable dimensions, even of 11 inches diameter, of adequate density and transparency, and nearly free from *striæ*. Guinand's plan consisted mainly in thoroughly mixing the melted "metal" with an iron rod. Guinand joined M. Frauenhoffer, of Munich, and one of the largest of the lenses produced by them, the diameter of which is 9 inches, is now in the observatory at Dorpat.

Guinand was long in communication with the Astronomical Society of London; and he sent over some discs of flint-glass, of which Messrs. Dollond and Herschel made a favourable report. A commission was formed, consisting of Herschel, Dollond, Faraday, and Roget, but owing to the annoying interferences of the excise officers, notwithstanding the Government had made some special exceptions in favour of those scientific experiments, the results were not practically of that high value which might have been expected. Many of the observations however were of great value. Amongst other discoveries might be named the remarkable heavy glass, the *Silico-borate of lead*, with which the discovery of the "so-called" magnetisation of a ray of light was made. M. Guinand died, and one of his sons worked with M. Bontemps, while the widow and another son set up works in Switzerland. From their manufactory some examples of lenses were sent to the Great Exhibition of 1851. M. Bontemps was in 1848 prevailed upon to accept the invitation of Messrs. Chance Brothers and Co. to unite with them in attempts they were then making to improve the quality of glass. They succeeded in producing discs of extraordinary dimensions in flint of 29 inches diameter, weighing two cwt., and of crown glass up to 20 inches. Messrs. Chance, at the recommendation of the jury, were induced to submit their disc of flint-glass to the operation of grinding, finishing, and other processes necessary in order to ascertain the uniformity of its density throughout, and its superior quality was fully established.

M. Maës of Clichy, near Paris, proposes to manufacture optical glass, with the addition of barytes, magnesia, and oxide of zinc, in combination with boracic acid. The glass manufactured by M. Maës is exceedingly beautiful, but the boracic acid renders it very expensive. M. Cauchoix, the eminent French optician, says, that out of ten object glasses, 4 inches in diameter, made with M. Guinand's flint-glass, eight or nine turned out very good, while out of an equal number of object glasses made of the flint-glass of the English and French manufactories, only one, or two at most, were found serviceable.

An achromatic object glass for telescopes and microscopes consists of at least two lenses; the one made with glass of lead, or flint glass, and the other with crown glass; the former possessing a power of dispersing the coloured rays relatively to its mean refractive power much greater than the latter; upon which principle, the achromatism of the image is produced, by re-uniting the different coloured rays into one focus. Three plans have been prescribed for obtaining homogeneous pieces of optical glass: 1, to lift a mass of it in large ladles, and let it cool in them; 2, to pour it out from the pots into moulds; 3, to allow it to cool in the pots, and afterwards to cut it off in

horizontal strata. The last method seldom affords pieces of uniform density, unless peculiar precautions have been adopted to settle the flint glass in uniform strata; because its materials are of such unequal density, the oxide of lead having a specific gravity of 8, and silica of 2·7, that they are apt to stand at irregular heights in the pots.

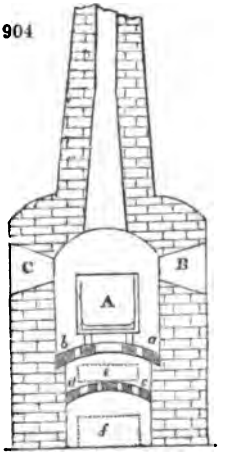
One main cause of these inequalities lies in the construction of the furnace, whereby the bottom of the pot is usually much less heated than the upper part. In a plate glass furnace the temperature of the top of the pot has been found to be 130° Wedgew., while that of the bottom was only 110°, constituting a difference of no less than 2610° F. The necessary consequence is that the denser particles which subside to the bottom during the fusion of the materials, and after the first extrication of the gases, must remain there, not being duly agitated by the expansive force of caloric, acting from below upwards.

The following suggestions, deduced from a consideration of principles, may probably lead to some improvements, if judiciously applied. The great object is to counteract the tendency of the glass of lead to distribute itself into strata of different densities; which may be effected either by mechanical agitation or by applying the greatest heat to the bottom of the pot. But however homogeneous the glass may be thereby made, its subsequent separation into strata of different densities must be prevented by rapid cooling and solidification. As the deeper the pots, the greater is the chance of unequal specific gravity in their contents, it would be advisable to make them wider and shallower than those in use for making ordinary glass. The intermixture may be effected either by lading the glass out of one pot into another in the furnace, and back again, with copper ladles, or by stirring it up with a rouser, then allowing it to settle for a short time, till it becomes clear and free from air bubbles. The pot may now be removed from the furnace, in order to solidify its contents in their homogeneous state; after which the glass may be broken in pieces, and be perfected by subjecting it to a second fusion; or what is easier and quicker, we may form suitable discs of glass without breaking down the potful, by lifting it out in flat copper ladles with iron shanks, and transferring the lumps after a little while into the annealing leer.—*Ure.*

To render a potful of glass homogeneous by agitation, is a most difficult task, as an iron rod would discolour it, and a copper rod would be apt to melt. An iron rod sheathed in laminated platinum would answer well, but for its expense. A stoneware tube supported within by a rod of iron, might also be employed for the purpose in careful hands; the stirring being repeated several times, till at last the glass is suffered to stiffen a little by decrease of temperature. It must be then allowed to settle and cool, after which the pot, being of small dimensions, may be drawn out of the fire.

2. The second method of producing the desired uniformity of mixture, consists in applying a greater heat to the bottom than to the upper part of the melting pot. *Fig.* 904 represents in section a furnace contrived to effect this object. It is cylindrical, and of a diameter no greater than to allow the flames to play round the pot, containing from three to four cwts. of vitreous materials. A is the pot, resting upon the arched grid *b a*, built of fire-bricks, whose apertures are wide enough to let the flames rise freely, and strike the bottom and sides of the vessel. From 1½ to 2 feet under that arch, the fuel grate *c d* is placed. B C are the two working openings for introducing the materials and inspecting the progress of the fusion; they must be closed with fire-tiles and luted with fire-clay at the beginning of the process. At the back of the furnace, opposite the mouth of the fire-place, there is a door-way, which is bricked up, except upon occasion of putting in and taking out the pot. The draught is regulated by means of a slide-plate, upon the mouth of the ash-pit *f*. The pot being heated to the proper pitch, some purified pearl ash, mixed with fully twice its weight of colourless quartz sand, is to be thrown into it, and after the complete fusion of this mixture, the remaining part of the sand, along with the oxide of lead (fine litharge), is to be strewn upon the surface. These siliceous particles in their descent serve to extricate the air from the mass. Whenever the whole is fused, the heat must be strongly urged to insure a complete uniformity of combination by the internal motions of the particles. As soon as the glass has been found by making test phials to be perfectly fine, the fire must be withdrawn, the two working-holes must be opened, as well as the mouths of

904



the fire-place and ash-pit to admit free ingress to cooling currents of air, so as to congeal the liquid mass as quickly as possible; a condition essential to the uniformity of the glass. It may be worth while to stir it a little with the pottery rod at the commencement of the cooling process. The solidified glass may be afterwards detached by a hammer in conchoidal discs, which after chipping off their edges, are to be placed in proper porcelain or stone-ware dishes, and exposed to a softening heat, in order to give them a lenticular shape. Great care must be taken that the heat thus applied by the muffle furnace be very equable, for otherwise wreathes might be very readily reproduced in the discs. A small oven upon the plan of a baker's, is best fitted for this purpose, which being heated to dull redness, and then extinguished, is ready to soften and afterwards anneal the conchoidal pieces.

Guinand's dense optical flint glass, of specific gravity 3·616, consists, by analysis, of oxide of lead, 43·05; silica, 44·3; and potash, 11·75; but requires for its formation the following ingredients:—100 pounds of ground quartz; 100 pounds of fine red lead; 35 pounds of purified potash; and from 2 to 4 pounds of saltpetre. As this species of glass is injured by an excess of potash, it should be compounded with rather a defect of it, and melted by a proportionably higher or longer heat. A good optical glass has been made in Germany with 7 parts of pure red lead, 3 parts of finely ground quartz, and 2 parts of calcined borax.

5. *Plate glass.*—This, like English crown-glass, has a soda flux, whereas flint-glass requires potash, and is never of good quality when made with soda. We shall distribute our account of this manufacture under two heads.

1. The different furnaces and principal machines, without whose knowledge it would be impossible to understand the several processes of a plate-glass factory.

2. The materials which enter into the composition of this kind of glass, and the series of operations which they undergo; devoting our chief attention to the changes and improvements which long experience, enlightened by modern chemistry, has introduced into the great manufactory of Saint-Gobain in France, under the direction of M. Tassaert. It may however be remarked that the English plate-glass manufacture derives peculiar advantages from the excellence of its grinding and polishing machinery.

The following description given by Dr. Ure refers almost entirely to the manufacture of plate glass in France. It is retained in nearly its original form, and is, in nearly all respects, equally applicable to the manufacture of the best plate glass in this country.

The clay for making the bricks and pots should be free from lime and iron, and very refractory. It is mixed with the powder of old pots passed through a silk sieve. If the clay be very plastic it will bear its own weight of the powder, but if shorter in quality, it will take only three-fifths. But before mingling it with the cement of old pots, it must be dried, bruised, then picked, ground, and finally elutriated by agitation with water, decantation through a hair sieve, and subsidence. The clay fluid after passing the sieve is called *slip* (*coulis*).

The furnace is built of dry bricks, cemented with slip, and has at each of its four angles a peculiar annealing arch, which communicates with the furnace interiorly, and thence derives sufficient heat to effect in part, if not wholly, the annealing of the pots, which are always deposited there a long time before they are used. Three of these arches, exclusively appropriated to this purpose, are called pot-arches. The fourth is called the *arch of the materials*, because it serves for drying them before they are founded. Each arch has, moreover, a principal opening called the throat, another called *bouvard*, by the French workmen, through which fire may be kindled in the arch itself, when it was thought to be necessary for the annealing of the pots; a practice now abandoned. The duration of a furnace is commonly a year, or at most 14 months; that of the arches is 30 years or upwards, as they are not exposed to so strong a heat.

In the manufacture of plate-glass two sorts of crucibles are employed, called the pots and the basins (*cuvettes*). The first serve for containing the materials to be founded, and for keeping them a long time in the melted state. The *cuvettes* receive the melted glass after it is refined, and decant it out on the table to be rolled into a plate. Three pots hold liquid glass for six small basins, or for three large ones, the latter being employed for making mirrors of great dimensions, that is, 100 inches long and upwards. Furnaces have been lately constructed with 6 pots, and 12 cuvettes, 8 of which are small, and 4 large; and cuvettes of three sizes are made, called *small*, *middling*, and *large*. The small are perfect cubes, the middling and the large ones are oblong parallelopipeds. Towards the middle of their height, a notch or groove, two or three inches broad, and an inch deep, is left, called the girdle of the cuvette, by which part they are grasped with the tongs, or rather are clamped in the iron frame. This frame goes round the four sides of the small cuvettes, and may be placed indifferently upon

all their sides; in the other cuvettes, the girdle extends only over the two large sides, because they cannot be turned up. See *m* T, *fig.* 905, p. 360.

The pot is an inverted truncated cone, like a crown glass pot. It is about 30 inches high, and from 30 to 32 inches wide, including its thickness. There is only a few inches of difference between the diameter of the top and that of the bottom. The bottom is three inches thick, and the body turns gradually thinner till it is an inch at the mouth of the pot.

The large building or factory, of which the melting furnace occupies the middle space, is called the *halle* in French. At Ravenhead in Lancashire it is called the foundry, and is of magnificent dimensions, its length is 339 feet, and its breadth 155. The famous *halle* of St. Gobain is 174 feet by 120. Along the two side walls of the *halle*, which are solidly constructed of hewn stone, there are openings like those of common ovens. These ovens, destined for the annealing of the newly cast plates, bear the name of *carquaises*. Their soles are raised two feet and a half above the level of the ground, in order to bring them into the same horizontal plane with the casting tables. Their length, amounting sometimes to 30 feet, and their breadth to 20, are required in order to accommodate 6, 8, or even 10 plates of glass alongside of each other. The front aperture is called the throat, and the back door the little throat (*gueulette*). The carquaise is heated by means of a fire-place of a square form called a *tisar*, which extends along its side.

The founding or melting furnace is a square brick building laid on solid foundations, being from 8 to 10 feet in each of its fronts, and rising inside into a vault or crown about 10 feet high. At each angle of this square, a small oven or arch is constructed, likewise vaulted within, and communicating with the melting furnace by square flues, called *lunettes*, through which it receives a powerful heat, though much inferior to that round the pots. The arches are so distributed as that two of the exterior sides of the furnace stand wholly free, while the two other sides, on which the arches encroach, offer a free space of only 3 feet. In this interjacent space, two principal openings of the furnace, of equal size in each side, are left in the building. These are called tunnels. They are destined for the introduction of the pots and the fuel.

On looking through the tunnels into the inside of the furnace, we perceive to the right hand and the left, along the two *free* sides, two low platforms or *sieges*, at least 30 inches in height and breadth. See *figs.* 896, 898.

These *sieges* (seats) being intended to support the pots and the cuvettes filled with heavy materials, are terminated by a slope, which ensures the solidity of the fire-clay mound. The slopes of the two sieges extend towards the middle of the furnace so near as to leave a space of only from 6 to 10 inches between them for the hearth. The end of this is perforated with a hole sufficiently large to give passage to the liquid glass of a broken pot, while the rest is preserved by lading it from the mouth into the adjoining cuvette.

In the two large parallel sides of the furnace, other apertures are left, much smaller than the tunnels, which are called *ouvreaux* (peep holes). The lower ones, or the *ouvreaux en bas*, called *cuvette* openings, because, being allotted to the admission of these vessels, they are exactly on a level with the surface of the *sieges*, and with the floor of the *halle*. Plates of cast iron form the thresholds of these openings, and facilitate the ingress and egress of the cuvettes. The apertures are arched at top, with hewn stone like the tunnels, and are 18 inches wide when the cuvettes are 16 inches broad.

The upper and smaller apertures, or the higher *ouvreaux*, called the *lading* holes, because they serve for transvasing the liquid glass, are three in number, and are placed 31 or 32 inches above the surface of the *sieges*. As the pots are only 30 inches high, it becomes easy to work through these openings either in the pots or the *cuvettes*. The pots stand opposite to the two pillars which separate the openings, so that a space is left between them for one or more *cuvettes* according to the size of the latter. It is obvious that if the tunnels and *ourreaux* were left open, the furnace would not draw or take the requisite founding heat. Hence the openings are shut by means of fire-tiles. These are put in their places, and removed by means of two holes left in them in correspondence with the two prongs of a large iron fork supported by an axle and two iron wheels, and terminated by two handles which the workmen lay hold of when they wish to move the tile.

The closing of the tunnel is more complex. When it is shut or ready for the firing, the aperture appears built up with bricks and mortar from the top of the arch to the middle of the tunnel. The remainder of the door-way is closed,—1. on the two sides down to the bottom, by a small upright wall, likewise of bricks, and 8 inches broad, called walls of the *glaye*; 2, by an assemblage of pieces called pieces of the *glaye*, because the whole of the closure of the tunnel bears the name of *glaye*. The upper hole, 4 inches square, is called the *tisar*, through which billets of wood are tossed into the

fire. Fuel is also introduced into the posterior openings. The fire is always kept up on the hearth of the tunnel, which is on this account, 4 inches higher than the furnace-hearth, in order that the glass which may accidentally fall down on it, and which does not flow off by the bottom hole, may not impede the combustion. Should a body of glass, however, at any time obstruct the grate, it must be removed with rakes, by opening the tunnel and dismounting the fire-tile stoppers of the *glaye*.

Formerly wood fuel alone was employed for heating the melting-furnaces of the mirror-plate manufactory of Saint-Gobain; but within these few years, the director of the works makes use with nearly equal advantage of pit-coal. In the same establishment, two melting furnaces may be seen, one of which is fired with wood, and the other with coals, without any difference being perceptible in the quality of the glass furnished by either. It is not true, as has been stated, that the introduction of pit-coal has made it necessary to work with covered pots in order to avoid the discolouration of the materials, or that more alkali was required to compensate for the diminished heat in the covered pots. They are not now covered when pit-coal is used, and the same success is obtained as heretofore by leaving the materials two or three hours longer in the pots and the cuvettes. The construction of the furnaces in which coal is burned is the same as that with wood, with slight modifications. Instead of the close bottomed hearth of the wood furnace, there is an iron grate in the coal-hearth through which the air enters, and the waste ashes descend.

When billets of wood were used as fuel, they were well dried beforehand, by being placed a few days on a frame work of wood called the wheel, placed two feet above the furnace and its arches, and supported on four pillars at some distance from the angles of the building.

The progress of chemistry, the discovery of a good process for the manufacture of soda from sea salt, which furnishes a pure alkali of uniform power, and the certain methods of ascertaining its purity, have rendered this department of glass-making far more certain than formerly. At Saint-Gobain no alkali is employed except artificial crystals of soda, prepared at the manufactory of Chauny, subsidiary to that establishment. The first crop of soda crystals is reserved for the plate-glass manufacture, the other crystals and the mother-water salts are sold to the makers of inferior glass.

If glass contains much lead it has a yellow tint. If manganese is present it changes by the action of light to a pale rose. Iron imparts a dull greenish tint; therefore the proportions of all those materials should be adjusted with great care.

At the mirror-plate works of Ravenhead, near St. Helen's in Lancashire, soda crystals, from the decomposition of the sulphate of soda by chalk and coal, have been also tried, but without equal success as at Saint-Gobain; the failure being unquestionably due to the impurity of the alkali. Hence, in the English establishment, the soda is obtained by treating sea-salt with pearl-ash, whence carbonate of soda and muriate of potash result. The latter salt is crystallised out of the mingled solution, by evaporation at a moderate heat, for the carbonate of soda does not readily crystallise till the temperature of the solution fall below 60° Fahr. When the muriate of potash is thus removed, the alkaline carbonate is evaporated to dryness.

Long experience at Saint-Gobain has proved that one part of dry carbonate of soda is adequate to vitrify perfectly three parts of fine siliceous sand, as that of the mound of Aumont near Senlis, of Alum Bay in the Isle of Wight, or of Lynn in Norfolk. It is also known that the degree of heat has a great influence upon the vitrification, and that increase of temperature will compensate for a certain deficiency of alkali; for it is certain that a very strong fire always dissipates a good deal of the soda, and yet the glass is not less beautiful. The most perfect mirror-plate has constantly afforded to M. Vauquelin, in analysis, a portion of soda inferior to what had been employed in its formation. Hence, it has become the practice to add, for every 100 parts of cullet or broken plate that is mixed with the glass composition, one part of alkali, to make up for the loss that the old glass must have experienced.

To the above mentioned proportions of sand and alkali, independently of the cullet which may be used, dry slaked lime carefully sifted is to be added to the amount of one seventh of the sand; or the proportion will be, sand, 7 cwt.; quicklime, 1 cwt.; dry carbonate of soda, 2 cwt. and 37 lbs.; besides cullet. The lime improves the quality of the glass; rendering it less brittle and less liable to change. The preceding quantities of materials, suitably blended, have been uniformly found to afford most advantageous results. The practice formerly was to dry that mixture, as soon as it was made, in the arch for the materials, but it has been ascertained that this step may be dispensed with, and the small portion of humidity present is dissipated almost instantly after they are thrown into the furnace. The coat of glaze previously applied to the inside of the pot, prevents the moisture from doing them any harm. For this reason, when the demand for glass at Saint-Gobain is very great, the materials are neither

fritted nor even dried, but shovelled directly into the pot; this is called founding *raw*. Six workmen are employed in shovelling in the materials either fritted or otherwise, for the sake of expedition, and to prevent the furnace getting cooled. One-third of the mixture is introduced at first; whenever this is melted, the second third is thrown in, and then the last. These three stages are called the first, second, and third fusion or founding.

According to the ancient practice, the founding and refining were both executed in the pots, and it was not till the glass was refined, that it was laded into the cuvettes, where it remained only 3 hours, the time necessary for the disengagement of the air bubbles introduced by the transvasion, and for giving the *metal* the proper consistence for casting At present, the period requisite for founding and refining is equally divided between the pots and the *cuvettes*. The materials are left 16 hours in the pots, and as many in the *cuvettes*; so that in 32 hours, the glass is ready to be cast. During the last two or three hours, the fireman or *tiseur* ceases to add fuel; all the openings are shut, and the glass is allowed to assume the requisite fluidity; an operation called *stopping* the glass, or *performing the ceremony*.

The transfer of the glass into the *cuvettes*, is called *lading* (*trejetage*). Before this is done, the cuvettes are cleared out, that is, the glass remaining on their bottom is removed, and the ashes of the firing. They are lifted red hot out of the furnace by the method presently to be described, and placed on an iron plate, near a tub filled with water. The workmen, by means of iron paddles 6 feet long, flattened at one end and hammered to an edge, scoop out the fluid glass expeditiously, and throw it into water; the *cuvettes* are now returned to the furnace, and a few minutes afterwards the lading begins.

In this operation, ladles of wrought iron are employed, furnished with long handles, which are plunged into the pots through the upper openings or lading holes, and immediately transfer their charge of glass into the buckets. Each workman dips his ladle only three times, and empties its contents into the cuvette. By these three immersions (whence the term *trejeter* is derived), the large iron spoon is heated so much that when plunged into a tub full of water, it makes a noise like the roaring of a lion, which may be heard to a very great distance.

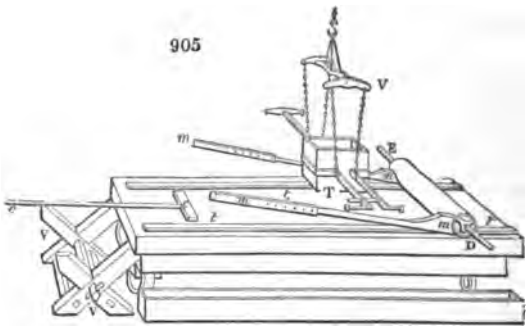
The founding, refining, and *ceremony* being finished, they next try whether the glass be ready for casting. With this view, the end of a rod is dipped into the bucket, which is called *drawing the glass*; the portion taken up being allowed to run off, naturally assumes a pear-shape, from the appearance of which they can judge if the consistence be proper, and if any air bubbles remain. If all be right, the *cuvettes* are taken out of the furnace, and conveyed to the part of the *halls* where their contents are to be poured out. This process requires peculiar instruments and manipulations.

Casting. — While the glass is refining, that is, coming to its highest point of perfection, preparation is made for the most important process, the casting of the plate, whose success crowns all the preliminary labours and cares. The oven or *carquaise* destined to receive and anneal the plate, is now heated by its small fire or *tisar* to such a pitch that its sole may have the same temperature as that of the plates, being nearly red-hot at the moment of their being introduced. An unequal degree of heat in the *carquaise* would cause breakage of the glass. The casting table is then rolled towards the front door or throat, by means of levers, and its surface is brought exactly to the level of the sole of the oven.

The table T, *fig.* 905, is a mass of bronze, or now preferably cast-iron, about 10 feet long, 5 feet broad, and from 6 to 7 inches thick, supported by a frame of carpentry, which rests on three cast-iron wheels. At the end of the table opposite to that next to the front of the oven, is a very strong frame of timber-work, called the puppet or standard, upon which the bronze roller which spreads the glass is laid, before and after the casting. This is 5 feet long by 1 foot in diameter; it is thick in the metal but hollow in the axis. The same roller can serve only for two plates at one casting, when another is put in its place, and the first is laid aside to cool; for otherwise the hot roller would, at a third casting, make the plate expand unequally, and cause it to crack. When the rollers are not in action, they are laid aside in strong wooden trestles, like those employed by sawyers. On the two sides of the table in the line of its length, are two parallel bars of bronze, *t*, *t*, destined to support the roller during its passage from end to end; the thickness of these bars determines that of the plate. The table being thus arranged, a crane is had recourse to for lifting the cuvette, and keeping it suspended, till it be emptied upon the table. This raising and suspension are effected by means of an iron gib, furnished with pulleys, held horizontally, and which turns with them.

The tongs, T, *fig.* 905, are made of four iron bars, bent into a square frame in their middle, for embracing the bucket. Four chains proceeding from the corners of the

frame v, are united at their other ends into a ring which fits into the hook of the crane. Things being thus arranged, all the workmen of the foundry co-operate in the manipu-



lations of the casting. Two of them fetch, and place quickly in front of one of the lower openings, the small cuvette-carriage, which bears a forked bar of iron, having two prongs corresponding to the two holes left in the fire-tile door. This fork, mounted on the axle of two cast-iron wheels, extends at its other end into two branches terminated by handles, by which the workmen move the fork, lift out the tile stopper, and set it down against the outer wall of the furnace.

The instant these men retire, two others push forward into the opening the extremity of the tongs-carriage, so as to seize the bucket by the girdle or rather to clamp it. At the same time, a third workman is busy with an iron pinch or long chisel, detaching the bucket from its seat, to which it often adheres by some spilt glass; whenever it is free, he withdraws it from the furnace. Two powerful branches of iron united by a bolt, like two scissor blades, which open, come together, and join by a quadrant near the other end, form the tongs-carriage, which is mounted upon two wheels like a truck.

The same description will apply almost wholly to the iron-plate carriage, on which the bucket is laid the moment it is taken out of the furnace; the only difference in its construction is, that on the bent iron bars which form the tail or lower steps of this carriage (in place of the tongs) is permanently fastened an iron plate, on which the bucket is placed and carried for the casting.

Whenever the *cuvette* is set upon its carriage, it must be rapidly wheeled to its station near the crane. The tongs T above described are now applied to the girdle, and are then hooked upon the crane by the suspension chains. In this position the bucket is skimmed by means of a copper tool called a sabre, because it has nearly the shape of that weapon. Every portion of the matter removed by the sabre is thrown into a copper ladle (*poche de gamin*), which is emptied from time to time into a cistern of water. After being skimmed, the bucket is lifted up, and brushed very clean on its sides and bottom; then by the double handles of the suspension-tongs it is swung round to the table, where it is seized by the workmen appointed to turn it over; the roller having been previously laid on its ruler bars, near the end of the table which is in contact with the annealing oven. The *cuvette*-men begin to pour out towards the right extremity E of the roller, and terminate when it has arrived at the left extremity D. While preparing to do so, and at the instant of casting, two men place within the ruler-bar on each side, that is, between the bar and the liquid glass, two iron instruments called *hands*, *m m*, *m m*, which prevent the glass from spreading beyond the rulers, whilst another draws along the table the wiping bar *c c*, wrapped in linen, to remove dust, or any small objects which may interpose between the table and the liquid glass.

Whenever the melted glass is poured out, two men spread it over the table, guiding the roller slowly and steadily along, beyond the limits of the glass, and then run it smartly into the wooden standard prepared for its reception, in place of the trestles v v.

The empty bucket, while still red-hot, is hung again upon the crane, set on its plate-iron carriage, freed from its tongs, and replaced in the furnace, to be speedily cleared out anew, and charged with fresh fluid from the pots. If, while the roller glides along, the two workmen who stand by with picking tools perceive *tears* in the matter in advance of the roller, and can dextrously snatch them out, they are suitably rewarded, according to the spot where the blemish lay, whether in the centre, where it would have proved most detrimental, or near the edge. These tears proceed usually from

small portions of semi-vitrified matter which fall from the vault of the furnace, and from their density occupy the bottom of the *cuvettes*.

While the plate is still red-hot and ductile, about 2 inches of its end opposite to the *carquaise* door is turned up with a tool; this portion is called the *head of the mirror*; against the outside of this head, the shovel, in the shape of a rake without teeth, is applied, with which the plate is eventually pushed into the oven, while two other workmen press upon the upper part of the head with a wooden pole, eight feet long, to preserve the plate in its horizontal position, and prevent its being warped. The plate is now left for a few moments near the throat of the *carquaise*, to give it solidity; after which it is pushed further in by means of a very long iron tool, whose extremity is forked like the letter y, and hence bears that name; and is thereby arranged in the most suitable spot for allowing other plates to be introduced.

However numerous the manipulations executed from the moment of withdrawing the *cuvette* from the furnace, till the cast-plate is pushed into the annealing oven, they are all performed in less than five minutes.

When all the plates of the same casting have been placed in the *carquaise*, it is sealed up; that is to say, all its orifices are closed with sheets of iron, surrounded and made tight with plastic loam. With this precaution, the cooling goes on slowly and equably in every part, for no cooling current can have access to the interior of the oven.

After they are perfectly cooled, the plates are carefully withdrawn one after another, keeping them all the while in a horizontal position, till they are entirely out of the *carquaise*. As soon as each plate is taken out, one set of workmen lower quickly and steadily the edge which they hold, while another set raise the opposite edge, till the glass be placed upright on two cushions stuffed with straw, and covered with canvas. In this vertical position they pass through, beneath the lower edge of the plate, three girths or straps, each four feet long, thickened with leather in their middle, and ending in wooden handles; so that one embraces the middle of the plate, and the other two the ends. The workmen, six in number, now seize the handles of the straps, lift up the glass closely to their bodies, and convey it with a regular step to the warehouse. Here the head of the plate is first cut off with a diamond square, and then the whole is attentively examined, in reference to its defects and imperfections, to determine the sections which must be made of it, and the eventual size of the pieces. The parings and small cuttings detached are set aside, in order to be ground and mixed with the raw materials of another glass-pot.

The apartment in which the roughing-down and smoothing of the plates is performed, is furnished with a considerable number of stone tables, truly hewn and placed apart like billiard tables, in a horizontal position, about 2 feet above the ground. They are rectangular, and of different sizes proportional to the dimensions of the plates, which they ought always to exceed a little. These tables are supported either on stone pillars or wooden frames, and are surrounded with a wooden board whose upper edge stands somewhat below their level, and leaves in the space between it and the stone all round an interval of 3 or 4 inches, of which we shall presently see the use.

A cast plate, unless formed on a table quite new, has always one of its faces, the one next the table, rougher than the other; and with this facing the roughing-down begins. With this view, the smoother face is cemented on the stone table with Paris-plaster. But often instead of one plate, several are cemented alongside of each other, those of the same thickness being carefully selected. They then take one or more crude plates of about one-third or one-fourth the surface of the plate fixed to the table, and fix it on them with liquid gypsum to the large base of a quadrangular truncated pyramid of stone, of a weight proportioned to its extent, or about a pound to the square inch. This pyramidal muller, if small sized, bears at each of its angles of the upper face a peg or ball, which the grinders lay hold of in working it; but when of greater dimension, there is adapted to it horizontally a wheel of slight construction, 8 or 10 feet in diameter, whose circumference is made of wood rounded so as to be seized with the hand. The upper plate is now rubbed over the lower ones, with moistened sand applied between.

This operation is however performed by machinery. The under plate being fixed or imbedded in stucco, on a solid table, the upper one likewise imbedded by the same cement in a cast-iron frame, has a motion of circumrotation given to it, closely resembling that communicated by the human hand and arm, moist sand being supplied between them. While an excentric mechanism imparts this double rotatory movement to the upper plate round its own centre, and of that centre round a point in the lower plate, this plate placed on a movable platform changes its position by a slow horizontal motion, both in the direction of its length and its breadth. By this ingenious contrivance, which pervades the whole of the grinding and polishing machinery, a remarkable regularity of friction and truth of surface is produced. When the plates are sufficiently worked on one face, they are reversed in the frames, and worked together

on the other. The Paris plaster is usually coloured red, in order to show any defects in the glass.

The smoothing of the plates is effected on the same principles by the use of moist emery washed to successive degrees of fineness, for the successive stages of the operation; and the polishing process is performed by rubbers of hat-felt and a thin paste of colcothar and water. The colcothar, called also crocus, is red oxide of iron prepared by the ignition of copperas, with grinding and elutriation.

The last part, or the polishing process, is performed by hand. This is managed by females, who slide one plate over another, while a little moistened *putty of tin* finely levigated is thrown between.

Large mirror-plates are now the indispensable ornaments of every large and sumptuous apartment; they diffuse lustre and gaiety round them, by reflecting the rays of light in a thousand lines, and by multiplying indefinitely the images of objects placed between opposite parallel planes. For the process of silvering, see MIRRORS.

Bohemian glass. — M. Peligot states that the hard glass of Bohemia is composed of 100 parts of silica, 12 parts of quicklime, and only 28 parts of carbonate of potash. These proportions give a glass quite unmanageable in ordinary furnaces; but the addition of a comparatively small quantity of boracic acid is capable of determining fusion, and the result is a glass having all the requisite limpidity at a high temperature, and possessing at the same time a great brilliancy and hardness.

The Bohemian glass is, within certain limits, perfectly elastic, and very sonorous; when well made, it is sufficiently hard to strike fire with steel, and is scratched with difficulty. The lead glasses, on the other hand, have but little hardness, and less in proportion as they contain more oxide of lead; besides which they rapidly lose their brilliancy by use.

The silica which is employed in Bohemia in the manufacture of glass, is obtained by calcining crystalline quartz, and afterwards pounding it while dry. When the quartz has been heated to a cherry-red, it is withdrawn from the fire, and thrown immediately into cold water.

Almost all the Bohemian glass is a potash glass, because soda and its salts give to glass a sensible yellowish tint. The limestone which is used is as white as Carrara marble. The clay employed for the crucibles is very white, and consists of silica, $45\frac{1}{10}$; alumina, $40\frac{4}{10}$; and water, $13\frac{8}{10}$.

The manufacture of glass in Bohemia is of very high antiquity, and the same peculiarities have always belonged to the true Bohemian manufacture.

In our modern times the Bohemian glass has been more especially celebrated for the beautiful varieties of colours which are produced. See GLASS, COLOURED.

Venetian glass. — From an early date the city of Venice has been celebrated for its glass; the *reticulated glass*, the *crackle glass*, and the glass paper weights, or *millefiore*, are all due to the Venetians.

The manufacture of *glass beads* at Murano, near Venice, has been carried on for an indefinite period, and Africa and Asia have been supplied from their glass-houses. The process is most ingeniously simple. Tubes of glass of every colour, are drawn out to great lengths in a gallery adjoining the glass-house pots, in the same way as the more moderate lengths of thermometer and barometer tubes are drawn in our glass-houses. These tubes are chopped into very small pieces of nearly uniform length on the upright edge of a fixed chisel. These elementary cylinders being then put in a heap into a mixture of fine sand and wood ashes, are stirred about with an iron spatula till their cavities get filled. This curious mixture is now transferred to an iron pan suspended over a moderate fire, and continually stirred about as before, whereby the cylindrical bits assume a smooth rounded form; so that when removed from the fire and cleared out in the bore, they constitute beads, which are packed in casks, and exported in prodigious quantities to almost every country. See GEMS, ARTIFICIAL.

The manufacture of reticulated glass for which Venice was equally celebrated, was long lost; it was at length revived by Pohl, and the crackle glass was in like manner reproduced by Mr. Apsley Pellatt in 1851.

The reticulated glass is produced by a kind of network consisting of small bubbles of air inclosed within the mass, and ranged in regular series crossing and interlacing each other. To produce this ornamental appearance, hollow glass cones or conical tubes are kept prepared, containing already this network arrangement of air bubbles. These tubes are made by arranging a number of small glass rods round a centre, so as to form a cylinder, and fixing them in this position by melted glass. The cylinder is then heated until the single rods stick together, when they are drawn out on the pipe to a long cone, and spirally twisted at the same time, the one half to the right and the other to the left, when one of these hollow cones is inserted into the other, and the two are heated until they fuse together; wherever the little rods cross each other a bubble of air will be inclosed, and this occurring in a very regular

manner, the reticulated appearance is produced. The Venetians were also celebrated for their "filigree." This glass has of late years been reintroduced in France and in this country. The process of manufacture has been thus described by Mr. Apsley Pellatt, in his *Curiosities of Glass Manufacture*:—

"Before ornaments or vessels can be blown, small filigree canes, with white or variously coloured enamels must be drawn. These are first 'whetted' off to the required lengths, and then put into a cylindrical mould with suitable internal recesses, and both cane and mould are thus submitted to a moderate heat. The selection of the colour of the canes depends upon the taste of the manufacturer: two to four white enamel canes are chiefly used, alternately, with about half the number of coloured. The blower then prepares a solid ball of transparent flint glass, which being deposited in contact with the various canes, at a welding heat, occasions them to adhere. This solid ball is then taken from the mould, is reheated, and '*marvered*' till the adhering projecting ornamental canes are rubbed into one uniform mass; the ball is next covered with a gathering of white glass, which must then be drawn to any size and length that may be required. Should a spiral cane be preferred, the 'pucellas' holds the apex in a fixed position, while the ornamental mass, still adhering to the glass maker's iron, is revolved during the process, till the requisite twist is given. Where vases are formed of alternately coloured and enamelled filigree canes, the above process is repeated, and the usual mode of blowing is followed."

The Venetian ball is a collection of waste pieces of filigree glass conglomerated together without regular design: this is packed into a pocket of transparent glass, which is adhesively collapsed upon the interior mass by sucking up, producing outward pressure of the atmosphere.

Millefiore, or star work of the Venetians, is similar to the last, only, the lozenges of glass are more regularly placed.

The *Vitro di Trino* of the Venetians is similar to the filigree in many respects; but by closing an outer on the inner case, each containing filigree canes, a bubble of air is inclosed between each crossing of the canes.

The celebrated frosted glass of the Venetians was reintroduced by Mr. Apsley Pellatt in 1851, who thus describes the process of manufacture:—"Frosted glass, like *Vitro di Trino*, is one of the few specimens of Venetian work not previously made by the Egyptians and the Romans; and not since executed by the Bohemian or French glass makers. The process of making it, until recently practised at the Falcon Glass Works, was considered a lost art. Frosted glass has irregularly varied marble-like projecting dislocations in its intervening fissures. Suddenly plunging hot glass into cold water, produces crystalline convex fractures, with a polished exterior, like Derbyshire spar; but the concave intervening figures are caused, first by chilling, and then reheating at the furnace, and simultaneously expanding the reheated ball of glass by blowing; thus separating the crystals from each other, and leaving open figures between, which is done preparatory to forming vases or ornaments. Although frosted glass appears covered with fractures, it is perfectly sonorous."

GLASS, COLOURED. Most of the metallic oxides impart a colour to glass, and some non-metallic, and even some substances derived from the organic kingdom have the power of imparting permanent colours to the vitreous combinations of flint and potash. There is much in this subject which still requires examination. M. Bontemps, at the meeting of the British Association at Birmingham, brought forward some very extraordinary facts in connection with the colouring powers of different bodies. Of his communication the following is an abstract.

In the first place it was shown, that all the colours of the prismatic spectrum might be given to glass by the use of the oxide of iron in varying proportions, and by the agency of different degrees of heat: the conclusion of the author being, that all the colours are produced in their natural disposition in proportion as you increase the temperature. Similar phenomena were observed with the oxide of manganese. Manganese is employed to give a pink or purple tint to glass, and also to neutralise the slight green given by iron and carbon to glass in its manufacture. If the glass coloured by manganese remains too long in the melting-pot or the annealing-kiln, the *purple* tint turns first to a light *brownish red*, then to *yellow*, and afterwards to *green*. White glass, in which a small proportion of manganese has been used, is liable to become light yellow by exposure to luminous power. This oxide is also, in certain window glass, disposed to turn pink or purple under the action of the sun's rays. M. Bontemps has found that similar changes take place in the annealing oven. He has determined, by experiments made by him on polygonal lenses for M. Fresnel, that light is the agent producing the change mentioned: and the author expresses a doubt whether any change in the oxidation of the metal will explain the photogenic effect. A series of chromatic changes of a similar character were observed with the oxides of copper, the colours being in like manner regulated by the heat to which

the glass was exposed. It was found that silver, although with less intensity, exhibited the same phenomena; and gold, although usually employed for the purpose of imparting varieties of red, was found by varying degrees of heating at a high temperature, and recasting several times, to give a great many tints, varying from blue to pink, red, opaque yellow, and green. Charcoal in excess in a mixture of silica-alkaline glass gives a yellow colour, which is not so bright as the yellow from silver: and this yellow colour may be turned to a dark red by a second fire. The author is disposed to refer these chromatic changes to some modifications of the composing particles rather than to any chemical changes in the materials employed.

It is not possible in the present essay to enter into the minute details of this beautiful branch of glass manufacture. In the following statement the materials ordinarily employed to colour glass alone are named.

YELLOW. *Charcoal* or soot is used for producing the commoner varieties of yellow glass.

The glass of antimony, which is obtained by roasting sulphide of antimony until antimonious acid is formed, and melting it with about 5 per cent. of undecomposed sulphide of the same metal.

The antimoniate of potash, a preparation similar to James's powder, is stated to answer the same purpose. Bohemian glass is coloured yellow with glass of antimony, minium, and oxide of iron.

Silver imparts a very beautiful yellow colour to glass; but it requires some caution in its mode of application. It is believed, that the presence of alumina is necessary to the production of colour, since a fine yellow cannot be produced unless alumina be present. A mixture of powdered clay and chloride of silver is prepared, and spread upon the surface of the glass; the glass is then reheated and the silver penetrates to a certain depth into the glass, before the latter softens. The coating is then scraped off and the fine yellow colour appears. If the silver yellow glass is held over the flame of burning wood, a peculiar opalescence is produced upon the surface, probably by the oxidation of the silver.

Uranium produces the beautiful canary yellow, which is found in many articles of an ornamental kind. This glass possesses the very peculiar property of giving a green colour when it is looked *at*, although perfectly and purely yellow when looked *through*. This has been attributed to the presence of iron in the commercial oxide of uranium employed; but the purer the uranium is, the more beautifully will this phenomenon be brought out. It depends upon a very remarkable physical peculiarity belonging to uranium and some other bodies. See FLUORESCENCE.

RED. A common brownish red colour is produced in glass by *oxide of iron*, added as ochre, or in the state of pure peroxide. Muller found ancient red glass to contain silicic acid, alkalies, lime, magnesia, alumina, protoxide of iron, and suboxide of copper.

Copper is more generally employed in colouring glass red. The use of this metal for this purpose dates from very high antiquity, and all through the middle ages it was employed to produce the reds which we see in the fine old windows left by our ancestors for our admiration. The ancient *Hæmatinone* was a copper red glass. Suboxide of copper is used, either in the state of commercial copper scale, or it is prepared by heating copper turnings to redness. If, during the fusion of the glass in the pot, the sub-oxide unites with an additional quantity of oxygen, green and not red is the result. This is avoided by combining some reducing agent with the melted substance. Glass thus coloured does not exhibit its red colour on leaving the crucible; it is nearly colourless, or with a tinge of green even when cold; but if it is then heated a second time it assumes the red colour. H. Rose supposes that a colourless neutral or acid silicate of the sub-oxide of copper is formed at a high temperature, and that the subsequent softening of the glass at a lower temperature causes the decomposition of this compound and a separation of a portion of the sub-oxide. We believe that no such chemical change takes place, and that the alteration is due merely to a change in the molecular arrangement of the particles. The sub-oxide of copper possesses an intense colouring power, so great indeed that glass coloured with even a very small quantity is almost impermeable to light; hence it is usual merely to *flash* colourless glass with this coloured glass, that is, to spread a very thin film of it over the colourless surface. A process for colouring glass red after its manufacture with sulphide of copper has been introduced by Bedford.

Gold can according to circumstances be made to impart a ruby, carmine, or pink tint to glass. The purple of Cassius, was employed; but Dr. Fuss first showed that a mere solution of gold without the presence of tin, as in the salt named, is capable of producing rose and carmine coloured glass.

Similar changes to those already described with copper occur with the salts of gold. Perhaps the glass is colourless in the pot, and it then remains colourless when cold; but when reheated, the glass quickly assumes a light red colour, which rapidly

spreads from the heated point over the whole glass, and increases in intensity until it becomes nearly a black red. This coloured glass can be again rendered colourless by fusion and slow cooling; its colour is again produced by a repetition of the heating process. If, however, it is suddenly cooled it cannot again be made to resume its ruby colour. This is also an example confirmatory in the highest degree of the view, that no chemical change takes place; but that all the phenomena are due to alterations in molecular structure. The practice of *flashing* colourless glass with the ruby glass from gold is commonly adopted. The beautiful examples of the Bohemian glass manufacture, in which we have a mixture of rich ruby and the purest crystal, are produced in this way. A globe of hot colourless glass is taken from the pot, and a cake of ruby glass prepared with a composition called *schmebze*, is warmed and brought into contact with the melted globe; this ruby glass rapidly diffuses itself over the surface, and the required article is blown or moulded with a coating of glass, coloured ruby by gold, of any required thickness.

Schmebze is prepared with 500 parts of silica, 800 of minium, 100 of nitre, and the same quantity of potash. A very small portion of a solution of gold in *aqua regia* is intimately mixed with 500 parts of schmebze, 43 parts of prismatic borax, 3 or 4 of oxide of tin, and a similar quantity of oxide of antimony. This mixture is heated for twelve hours in an open crucible placed in a flat furnace, and then cooled slowly in an annealing oven. A *Bohemian ruby*, especially so called, is prepared by melting together fulminating gold rubbed in with oil of turpentine, quartz powdered, and fritted minium, sulphide of antimony, peroxide of manganese, and potash. Böhme has given an analysis of a Venetian ruby glass, in which $\frac{1}{30}$ of a grain of gold is combined with about 150 of the ordinary ingredients of glass, with some tin and iron.

Manganese is sometimes employed to give a fine amethystine colour to glass; care is however required to prevent the reduction of the peroxide of manganese in the process.

GREEN. Green colours may be obtained by a variety of metallic oxides. *Protoxide of iron* imparts a dull green; an emerald green colour is given by *oxide of copper*. Either copper scales or verdigris dried and powdered are employed, the colour being much finer with a lead glass, than with one containing no lead. Translucent or *dull glass* is converted into a deep blue or turquoise colour by oxide of copper and not into a green. An emerald green is also produced by the *oxide of chromium*. Two kinds of Bohemian green glass, known respectively as the ancient and modern emerald greens, are prepared from mixtures of the oxides of nickel and of uranium.

BLUE. The only fine blue is produced by cobalt. The manufacture of *smalt* or *zaffre* is so important that it will be treated of in a separate article. See SMALT and COBALT.

BROWN. Peroxide of manganese with zaffre yields a fine garnet-like brown.

PINK or FLESH COLOUR. Oxide of iron and alumina, obtained by heating a mixture of alum and green vitriol.

ORANGE. Peroxide of iron with chloride of silver.

JASPER. A Bohemian glass, generally black, but of fine lustre, prepared by adding forge scales, charcoal, and bone ashes to the ordinary materials for glass.

Amongst the different varieties of glass, artificial gems may be enumerated. For a description of their manufacture, see GEMS, ARTIFICIAL.

GLASS, *its physical conditions and chemical constitution*. — So far as may be inferred, from the analysis of ordinary commercial samples of window-glass, this substance has not only a very variable composition, but, worse than this, it is out of all keeping with anything like definite proportion. That it should be full of striæ, and, therefore, refract the rays of light unequally, as it does, so as to produce the most hideous appearances of distortion, is a mere natural consequence of its mechanical composition, which might, and must one day be corrected; but that whole nations should have come to view this defect as an unavoidable peculiarity, is precisely one of those surprising facts which demonstrate the influence of habit over the powers of the mind, and show how easily human reason can reconcile itself to the most gross inconsistencies. If window-glass had one uniform atomic composition, the tendency to form these striæ would nowhere exist in excess; and, therefore, their production would diminish as the skill of the workmen increased; but, with the present variable compound, the glass stretches unequally in different parts, by an equal application of force, and, in spite of human skill, presents a result alternately thick or thin, as accident determines. That these striæ have not the same composition as the parts surrounding them is very obvious, from the circumstance that, if striated glass be cut to an uniform thickness, and polished on both sides, the optical defects remain but little changed, and occasionally they are found to be increased. Again it is known, that the more complex the composition of any glass may be, the greater the liability to this striated structure, — of which flint glass offers an apposite illustration; for here, in

addition to the ordinary components of glass, the silicate of lead is superadded. Now the specific gravity of silicate of lead is very high compared with that of silicate of soda, potash, or lime; hence, unless employed in the exact quantity to form a chemical combination with the other silicates, a mere mechanical mixture is produced of very different densities throughout; and the product, under the action of light, displays, permanently, that peculiar fugitive appearance seen when syrup and water, or alcohol and water, are mixed together; that is to say, a series of curved lines are formed by the unequal refraction of the two fluids, which entirely disappear, so soon as perfect admixture has taken place, but which remain in the case of flint-glass, from the utter impossibility of effecting the necessary union between its various parts. Although, however, this cannot be done mechanically, yet, in a chemical way, nature performs such operations with ease and unerring fidelity. The French chemist, Berthier, long ago proved that many neutral salts combine together by fusion in atomic proportions, and form new and definite compounds. Thus, carbonate of potash and carbonate of soda when mixed, atom for atom, unite and produce a compound more easy of fusion than the most fusible of the two: — similarly, either of these carbonates will act with carbonate of baryta or strontia, and again, fluor-spar and sulphate of lime, two remarkably infusible substances, when mixed, melt readily, at a low red heat into a fluid as mobile and transparent as water. It is useless to multiply examples of this kind, for thousands exist; and the alkaline and earthy silicates form no exception to this almost universal rule. A mixture of silicate of potash and silicate of soda will, if in atomic ratios, fuse much more readily than either of them alone. But now, let us imagine an attempt to fuse these two bodies together, in any other proportion than that in which they are naturally disposed to combine; — say that the silicate of soda is in excess; then the silicate of potash would unite with exactly sufficient of the silicate of soda to produce the extremely fusible compound above spoken of; whilst the less easily fusible silicate of soda, added in excess, would form a kind of network throughout the mass. It may be said, that a higher heat would overcome this difficulty, by thoroughly liquefying the silicate of soda; and this is really the plan now used with that view; but, independent of the fact that the mixed silicate of potash and soda would also undergo a corresponding liquefaction, and, therefore, favour the separation of the silicate of soda; yet, as chemical union is impossible, from the very conditions of the experiment, even the most perfect mechanical mixture, under the greatest advantages of fluidity, would never generate a homogeneous body. The striæ might, indeed, be diminished in size; but this would imply a corresponding increase in their number; and, if carried very far, complete opacity would result from such an endeavour to subvert the laws of nature. The power of the workmen to remedy this defect is therefore limited to the capability of modifying its more salient features; he can neither remove nor destroy it. What we have here illustrated by the simplest of all assumptions, gathers and accumulates into a formidable evil when several silicates are fused together, having considerable differences of specific weight. Thus, in the case of flint-glass before alluded to, there are generally three, and sometimes five, of these silicates fused together, into, probably, one of the most antagonistic compounds that could be conceived, refracting and dispersing the ray of light in fifty directions, and demonstrating the unfriendly nature of its coerced union, by flying in pieces from the most trivial applications of heat or violence. Yet in flint-glass we are not surpassed, nor indeed equalled, by any other nation; and so thoroughly has this beautiful substance become associated with our industrial reputation, that the British name, flint-glass, has been adopted into several continental languages. Nevertheless, it cannot be doubted that a wide field of improvement is open in this quarter, and that some more solid foundation is needed by our manufacturers in this line, than the prestige of a name, or the force of capital.

In France, as in England, the ingredients are mixed with some care, and introduced into a crucible, heated by a powerful furnace. These ingredients are sand or silica, carbonate of soda, and carbonate of lime, with perhaps a little ground felspar in some cases. The carbonate of soda is first attacked by the silica, and its carbonic acid driven off, whilst the remaining silica and carbonate of lime become imbedded in the vitrifying mass. As the heat increases, a more perfect fusion takes place; and then the carbonic acid of the carbonate of lime makes its way through the fused materials by which they are mechanically mingled together during the effervescence, which is technically termed the "boil;" and, provided no after separation ensues from the process of "settling," the whole crucible or "pot" of glass will have a uniform composition. But, as we have seen, this depends altogether upon the relative proportion of the materials towards each other, for an excess of either one or other of the bases will destroy the homogeneous character of the whole, and introduce a plexus of striæ. Now the plate-glass of St. Gobain is almost exactly an atomic compound, and consists of one atom of the trisilicate of soda and one atom of the trisilicate of lime, with a

small percentage of alumina. The union is therefore complete; and when it is remembered that the celebrated French chemist, Gay-Lussac, was regularly employed as an adviser to this company, and that his son, M. Jules Lussac, retains that appointment to this day, it is not very surprising that our manufacturers are defeated in the article of plate-glass. Science must ever take the lead of prejudice and custom.

The examination of English plate-glass fully corroborates the general result deduced from the action of light. There is no approach to an atomic arrangement. The principal constituent is trisilicate of soda, but variable quantities of lime, alumina, and even magnesia, exist in it. Potash is sometimes present, and oxide of iron is invariably so; but in not one single instance, out of 17 samples examined with great care, could so much as a surmise of the doctrine of combining proportions be gathered from the result of the analyses. Similarly fruitless was a research instituted upon flint-glass, both British and foreign. Of 35 samples analysed, no satisfactory evidence could be adduced to favour the opinion that science had been a helpmate to industry, or was at all concerned in this branch of manufacture. There are, however, some points of vast interest associated with the practical working out of this matter. Potash is known to give a more brilliant and harder glass than soda, and alumina seems to tend in the same direction. The Bohemian glass, so celebrated throughout Europe, is a glass of this description, and contains silicate of alumina, silicate of lime, and silicate of potash, but not in chemical proportions. This glass is therefore striated, but it seems to permit of a more perfect decoration by metallic oxides than can be developed in glass of lime and soda. This very probably depends upon the alumina contained in it. From some singular oversight, the use of carbonate of baryta has not yet found its way into the composition of glass, though we can scarcely conceive a more hopeful material. This substance may be had in large quantity in the North of England, of great purity, and at a merely nominal cost as compared with its value for such a purpose as glass-making. That it would fuse readily with a due amount of soda, and give "a boil" as well as chalk, there can be no doubt; whilst its great density will certainly improve the refractive power of the resulting product, and thus rival the brilliancy of lead or flint-glass, without imparting that softness and liability to receive scratches which are so objectionable in the latter variety. One difficulty may perhaps reside in the want of information concerning the quantity to be employed. But this is easily adjusted; for it has been demonstrated that, during vitrification, the silicic acid unites to bases in the proportion of three atoms to one: consequently three atoms, or 138 parts, will always require one atom of each base. Therefore, this weight of good dry sand may be set against 54 of dry carbonate of soda, 70 of carbonate of potash, 50 of pure marble or chalk, 99 of carbonate of baryta, and 112 of oxide of lead or litharge. Suppose, then, that the object is to employ carbonate of baryta for the first time, here 6 atoms or 276 parts of sand, 1 atom or 54 parts of dry carbonate of soda, and 1 atom or 99 parts of carbonate of baryta, may be mixed and fused together with every prospect of obtaining a good result; or 9 atoms of silica, 1 of carbonate of potash, 1 of carbonate of soda, and 1 of carbonate of baryta, might be tried without fear of failure. Again, in the case of flint-glass, 112 of litharge, 54 of soda, and 276 of sand, would probably succeed, or an additional atom of trisilicate of potash might be used. For many years past, M. Dumas, now, perhaps, the first chemist in France, has been in the habit of demonstrating to his pupils that glass of all kinds, when properly made, must necessarily be an atomic compound; and yet we scarcely expect to find a single British glassmaker who will admit that his art is susceptible of such decisive and beautiful simplification.

To assist as far as we can in the attainment of this end, we shall proceed to describe a simple means for the analysis of glass, which will enable any person, possessed of even very trifling chemical skill, to determine the composition of any given sample of glass in a comparatively short time. From the nature of the material, it becomes necessary to divide the analysis into two distinct portions; one of which has for its object the estimation of its alkaline ingredients, the other that of the earthy, metallic, and siliceous matters. Having heated a sufficient quantity of the sample in question to dull redness, it must be suddenly thrown, whilst still hot, into a basin containing cold water. In this way it becomes cracked and flawed in all directions, so as to favour its reduction into powder. When dry it must, therefore, be carefully ground in an agate or steel mortar, until it has the appearance of fine flour. Nor is it a matter of indifference whether this takes place in contact with water or not; for glass in this extreme state of comminution, readily gives up a part of its alkali to water; and hence, if ground in the presence of that fluid, the resulting analysis would prove incorrect. But we will suppose that a quantity of finely powdered glass has been obtained as above indicated, and the amount of its alkali is desired; then weigh out 100 grains of the glass, and carefully mix with it 200 grains of pure fluor spar in a similarly powdered condition. Place the mixture in a platinum or leaden vessel, and

pour over it 500 grains of strong sulphuric acid, — stirring the whole well together with a silver spoon, but taking care not to remove any portion of the materials. Next, apply a heat of about 212° Fahr.; and as the process draws to a conclusion, this may be raised as high as 300°. When all evolution of gaseous fumes has ceased, water may be poured on the residuary mass to the extent of four or five ounces, and the mixture thrown on a filter. After the clear fluid has passed through, a little more water must be added to the filter, so as to wash out the whole of the soluble matter; these washings being joined to the original clear fluid, which consists of sulphate of soda or potash, or both, with a quantity of sulphate of lime, and perhaps also of magnesia and alumina. To this an excess of carbonate of ammonia must now be added, to admit of the separation of the earthy salts being effected by filtration. The clear solution is next boiled down to dryness, and the residue is heated red-hot for a minute or two. This residue is the soda or potash, or both, formerly contained in 100 grains of the glass, but now united to sulphuric acid. Having ascertained its weight, the relative proportions of potash and soda may be found by testing its content of sulphuric acid with a barytic solution, and calculating the result by the well-known Archimedean equation; or by dissolving the mixed salt in a small quantity of water, and, after adding an excess of tartaric acid, leaving the whole for a few hours covered up in a cool place. Almost the whole of the potash will separate in this way as bitartrate of potash. The quantity of alkali may be determined from the atomic constitution of the alkaline salts. Thus, supposing the dry residue altogether composed of sulphate of soda, then as 72 grains of it indicate 32 of pure soda, the result may be obtained by the rule of proportion. The amount of alkali being known, another portion of the powdered glass must be employed for ascertaining the remainder of the ingredients. That is to say, 100 grains of the sample must be mixed with 200 grains of pure potash, and the whole fused together in a silver crucible, at a red heat, until perfect liquefaction ensues, when the crucible and its contents may be withdrawn from the fire, and, as soon as cool enough, boiled in half a pint of pure water, so as thoroughly to dissolve the fused mass from the crucible. An excess of nitric acid being poured into the solution, the mixture is then evaporated to dryness, by which means the silicic acid is rendered insoluble; consequently, on the application of water, this remains, and may be dried and weighed, whilst the lime, alumina, and lead of the glass may be separated from the soluble portion by the addition, first, of sulphuretted hydrogen, which separates the lead, then of ammonia, which throws down the alumina, and, next, by pouring in carbonate of ammonia, which precipitates the lime as a carbonate. Thus, therefore, the alkaline matters are found by one process, and the silica, earthy, and metallic constituents by another, both of which may be conducted at the same time. It has been recommended to employ carbonate of baryta in the analysis of glass; but the high temperature required with this substance dissipates a portion of the alkaline components, and thus leads to serious errors. Even mere fusion in a glass furnace expels soda from glass, and renders it more and more infusible; but this expulsion is much favoured by the presence of baryta. The above method of analysing glass is, therefore to be preferred to the baryta plan, by individuals not habitually engaged in manipulative chemistry.—*Ure.*

GLASS *for horticultural purposes.* — An impression taken up loosely in the first instance from some experiments on the action of the chemical rays of light, when made to permeate coloured glass, has led the public frequently to conceive that glasses which admitted freely the chemical rays were the most adapted to accelerate the growth of plants. No more mistaken view was ever entertained. At different periods in the life of a plant different influences are necessary; at one time the chemical force is required, at another the luminous power, and at another the calorific agent. The solar rays, as we receive them direct from the sun, have those forces exactly adjusted to produce the best possible conditions; but under some of the artificial conditions in which we place plants, it is important to know the conditions of the solar rays best suited to produce a given effect. This we must briefly attempt to explain: —

1. Seeds germinating absorb oxygen, and convert their starch into sugar; this is a purely chemical process, and demands the full power of the *chemical rays* (*actinism*).

2. Wood forming, from the decomposition of carbonic acid, is a function of the vital power of the plant, excited by *light* (*luminous force*).

3. Flowering and fruiting manifest compound actions, and appear to demand the combined power of *heat* (*calorific power*) and of the chemical rays.

Such are the three chief conditions in the phenomena of vegetable growth. Now *a*, a glass stained blue with cobalt admits the permeation of the chemical rays with great freedom, obstructing both light and heat; *b*, a glass stained yellow with silver, will powerfully obstruct the chemical rays, and allow the luminous rays to pass freely; *c*, deep copper or gold red glasses admit the maximum heat rays to pass freely, and in general allow of the permeation of a small quantity of the chemical rays.

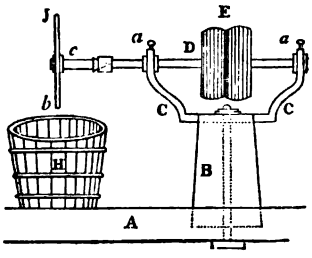
When seed is placed in the soil to germinate, a blue glass placed above the soil will greatly accelerate the process, the first leaves will appear above the soil, in many instances, days before they are seen when the seed is under the ordinary conditions in the soil; but if a plant is allowed to grow under these circumstances, scarcely any wood is produced, but long succulent stalks are formed, with imperfect leaves.

After germination has taken place, if the plant is brought under the influence of the rays permeating yellow glass (*light* separated to a considerable extent from the *chemical power*), wood is formed abundantly, and very healthy plants with dark leaves are produced. For the production of perfect flowers and fruit, the red glass named is the most effective. Plants growing in conservatories which have been glazed with the colourless German sheet glass, frequently suffer from scorching. To avoid this if possible, the editor of this volume was consulted on the glass which should be employed in glazing the great palm house at Kew, the problem being to avoid the necessity of blinds, and to secure the plants from the injurious action of the scorching rays. By a long series of experiments it was determined that glass stained green with a little of the oxide of copper, and from which there was an entire absence of the oxide of manganese, entirely effected this end. The great palm house in the Royal Botanic Gardens at Kew was glazed with glass made on this principle, by the Messrs. Chance Brothers and Co. of Birmingham, and it has now been tested by the sunshine of twelve summers (1859); and the plants, as every one may observe, grow most luxuriantly, and are entirely free from any indications of scorching on their leaves.

GLASS CUTTING AND GRINDING, for common and optical purposes. By this mechanical process the surface of glass may be modified into almost any ornamental or useful form.

1. *The grinding of crystal ware.* This kind of glass is best adapted to receive polished facets, both on account of its relative softness, and its higher refractive power, which gives lustre to its surface. The cutting shop should be a spacious long apartment, furnished with numerous skylights, having the grinding and polishing lathes arranged right under them, which are set in motion by a steam-engine or water-wheel at one end of the building. A shaft is fixed as usual in gallowses along the ceiling; and from the pulleys of the shaft, bands descend to turn the different lathes, by passing round the driving pulleys near their ends.

906



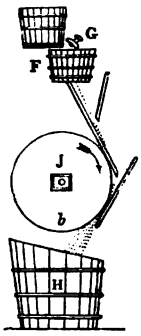
The turning lathe is of the simplest construction. *Fig.* 906, D, is an iron spindle with two well-turned prolongations, running in the iron puppets *a a*, between two concave boshes of tin or type metal, which may be pressed more or less together by the thumb-screws shown in the figure. These two puppets are made fast to the wooden support B, which is attached by a strong screw and bolt to the longitudinal beam of the workshop A. E is the fast and loose pulley for putting the lathe into and out of geer with the driving shaft. The projecting end of the spindle is furnished with a hollow head-piece, into which the rod *c* is pushed tight. This rod carries the cutting or grinding disc plate. For heavy work, this rod is fixed into the head by a screw. When a conical fit is preferred, the cone is covered with lead to increase the friction.

Upon projecting rods or spindles of that kind the different discs for cutting the glass are made fast. Some of these are made of fine sandstone or polishing slate, from 8 to 10 inches in diameter, and from $\frac{3}{4}$ to $\frac{1}{2}$ inch thick. They must be carefully turned and polished at the lathe, not only upon their rounded but upon their flat face, in order to grind and polish in their turn the flat and curved surfaces of glass vessels. Other discs of the same diameter, but only $\frac{3}{4}$ of an inch thick, are made of cast tin truly turned, and serve for polishing the vessels previously ground; a third set consists of sheet iron from $\frac{1}{4}$ to $\frac{1}{2}$ an inch thick, and 12 inches in diameter, and are destined to cut grooves in glass by the aid of sand and water. Small discs of well-hammered copper from $\frac{1}{2}$ to 3 inches in diameter, whose circumference is sometimes flat, and sometimes concave or convex, serve to make all sorts of delineations upon glass by means of emery and oil. Lastly, there are rods of copper or brass furnished with small hemispheres from $\frac{1}{16}$ to $\frac{1}{4}$ of an inch in diameter, to excavate round hollows in glass. Wooden discs are also employed for polishing, made of white wood cut across the grain, as also of cork.

The cutting of deep indentations, and of grooves, is usually performed by the iron

disc, with sand and water, which are allowed constantly to trickle down from a wooden hopper placed right over it, and furnished with a wooden stopple or plug at the apex, to regulate by its greater or less looseness the flow of the grinding materials. The same effect may be produced by using buckets as shown in *fig.* 907. The sand which is contained in the bucket F, above the lathe, has a spigot and faucet inserted near its bottom, and is supplied with a stream of water from the stopcock in the vessel G, which, together, running down the inclined board, are conducted to the periphery of the disc as shown in the figure, to whose lowest point the glass vessel is applied with pressure by the hand. The sand and water are afterwards collected in the tub H. Finer markings which are to remain without lustre, are made with the small copper discs, emery, and oil. The polishing is effected by the edge of the tin disc, which is from time to time moistened with putty (white oxide of tin) and water. The wooden disc is also employed for this purpose with putty, colcothar, or washed tripoli. For fine delineations, the glass is first traced over with some coloured varnish, to guide the hand of the cutter.

907



In grinding and facetting crystal glass, the deep grooves are first cut, for example, the cross lines, with the iron disc and rounded edge, by means of sand and water. That disc is one sixth of an inch thick and 12 inches in diameter. With another iron disc about half an inch thick, and more or less in diameter, according to the curvature of the surface, the grooves may be widened. These roughly cut parts must be next smoothed down with the sandstone disc and water, and then polished with the wooden disc about half an inch thick, to whose edge the workman applies, from time to time, a bag of fine linen containing some ground pumice moistened with water. When the cork or wooden disc edged with hat felt is used for polishing, putty or colcothar is applied to it. The above several processes in a large manufactory, are usually committed to several workmen on the principle of the division of labour, so that each may become expert in his department.

2. *The grinding of optical glasses.* — The glasses intended for optical purposes being spherically ground, are called lenses; and are used either as simple magnifiers and spectacles, or for telescopes and microscopes. The curvature is always a portion of a sphere, and either convex or concave. This form insures the convergence or divergence of the rays of light that pass through them, as the polishing does the brightness of the image.

The grinding of the lenses is performed in brass moulds, either concave or convex, formed to the same curvature as that desired in the lenses; and may be worked either by hand or by machinery. A gauge is first cut out of brass or copper plate to suit the curvature of the lens, the circular arc being traced by a pair of compasses. In this way both a convex and concave circular gauge are obtained. To these gauges the brass moulds are turned. Sometimes, also, lead moulds are used. After the two moulds are made, they are ground face to face with fine emery.

The piece of glass is now roughed into a circular form by a pair of pincers, leaving it a little larger than the finished lens ought to be, and then smoothed round upon the stone disc, or in an old mould with emery and water, and is next made fast to a holdfast. This consists of a round brass plate having a screw in its back; and is somewhat smaller in diameter than the lens, and two thirds as thick. This is turned concave upon the lathe, and then attached to the piece of glass by drops of pitch applied to several points of its surface, taking care, while the pitch is warm, that the centre of the glass coincides with the centre of the brass plate. This serves not merely as a holdfast, by enabling a person to seize its edge with the fingers, but it prevents the glass from bending by the necessary pressure in grinding.

The glass must now be ground with coarse emery upon its appropriate mould, whether convex or concave, the emery being all the time kept moist with water. To prevent the heat of the hand from affecting the glass, a rod for holding the brass plate is screwed to its back. For every six turns of circular motion, it must receive two or three rubs across the diameter in different directions, and so on alternately. The middle point of the glass must never pass beyond the edge of the mould; nor should strong pressure be at any time applied. Whenever the glass has assumed the shape of the mould, and touches it in every point, the coarse emery must be washed away, finer be substituted in its place, and the grinding be continued as before, till all the scratches disappear, and a uniform dead surface be produced. A commencement of polishing is now to be given with pumice-stone powder. During all this time the convex mould should be occasionally worked in the concave, in order that both may preserve their correspondence of shape between them. After the one surface has

been thus finished, the glass must be turned over, and treated in the same way upon the other side.

Both surfaces are now to be polished. With this view equal parts of pitch and resin must be melted together, and strained through a cloth to separate all impurities. The concave mould is next to be heated, and covered with that mixture in a fluid state to the thickness uniformly of one quarter of an inch. The cold convex mould is now to be pressed down into the yielding pitch, its surface being quite clean and dry, in order to give the pitch the exact form of the ground lens; and both are to be plunged into cold water till they be chilled. This pitch impression is now the mould upon which the glass is to be polished, according to the methods above described, with finely washed colcothar and water, till the surface become perfectly clear and brilliant. To prevent the pitch from changing its figure by the friction, cross lines must be cut in it about ¼ an inch asunder, and 1-12th of an inch broad and deep. These grooves remove all the superfluous parts of the polishing powder, and tend to preserve the polishing surface of the pitch clean and unaltered. No additional colcothar after the first is required in this part of the process, but only a drop of water from time to time. The pitch gets warm as the polishing advances, and renders the friction more laborious from the adhesion between the surfaces. No interruption must now be suffered in the work, nor must either water or colcothar be added; but should the pitch become too adhesive, it must be merely breathed upon, till the polish be complete. The nearer the lens is brought to a true and fine surface in the first grinding, the better and more easy does the polishing become. It should never be submitted to this process with any scratches perceptible in it, even when examined by a magnifier.

As to small lenses and spectacle eyes, several are ground and polished together. The pieces of glass are affixed by means of a resinous cement to the mould, close to each other, and are then all treated as if they formed but one large lens. Plane glasses are ground upon a surface of pitch rendered plane by the pressure of a piece of plate glass upon it in its softened state.

Lenses are also ground and polished by means of machinery, into the details of which the limits of this work will not allow us to enter. See LENSES.

GLASS PAPER and CLOTH. Paper or cloth being covered with glue, sand, varying in its degree of fineness, is dusted over it, and of course adheres. These are used for polishing, or removing the rough surfaces of woods or metals.

GLAUBER'S SALTS (the *Sal catharticus Glauberi*, or *Sal mirabile Glauberi*). Sulphate of soda was discovered by Glauber in 1658. Its composition is:—

Soda	19·24
Sulphuric acid	24·76
Water	56·00
	100·00

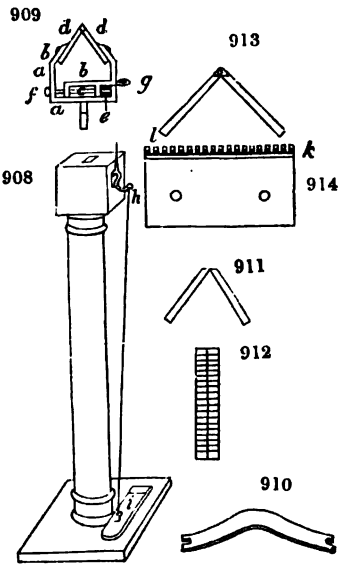
GLAZES. See POTTERY.

GLAZIER, is the workman who cuts plates or panes of glass with the diamond, and fastens them by means of putty in frames or window casements. See DIAMOND, for an explanation of its glass-cutting property.

GLAZING. The process of giving a hard polished surface to bodies. Paper is glazed by the use of resins, gelatine, &c. See PAPER. Pottery is glazed by the use of certain fusible materials. See POTTERY and PORCELAIN. Some metals are said to be "glazed" when, by means of polishing wheels, the highest finish is put upon their surfaces.

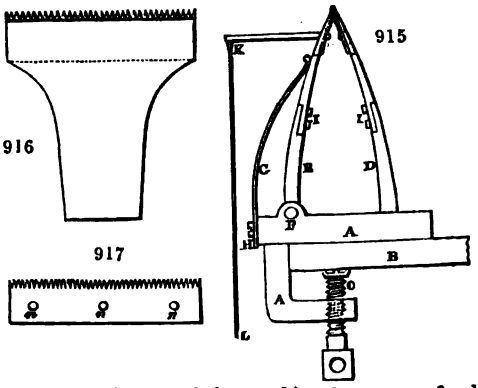
GLOVE MANUFACTURE. In February, 1822, Mr. James Winter of Stoke-under-Hambdon, in the county of Somerset, obtained a patent for an improvement upon a former patent machine of his for sewing and pointing leather gloves. *Fig.* 908, represents a pedestal, upon which the instrument called the jaws is to be placed. *Fig.* 909 shows the jaws, which instead of opening and closing by a circular movement upon a joint, as described in the former specification, are now made to open and shut by a parallel horizontal movement, effected by a slide and screw; *a a* is the fixed jaw, made of one piece, on the under side of which is a tenon, to be inserted into the top of the pedestal. By means of this tenon the jaws may be readily removed, and another similar pair of jaws placed in their stead, which affords the advantage of expediting the operation by enabling one person to prepare the work whilst another is sewing; *b b* is the movable jaw, made of one piece. The two jaws being placed together in the manner shown at *fig.* 910, the movable jaw traverses backwards and forwards upon two guide-bars, *c*, which are made to pass through holes exactly fitted to them, in the lower parts of the jaws. At the upper parts of the jaws are what are called the indexes, *d d*, which are pressed tightly together by a spring shown at *fig.* 911, and intended to be introduced between the perpendicular ribs of the jaws at *e*. At *f* is a thumb-screw, passing through the ribs for the purpose of

tightening the jaws, and holding the leather fast between the indexes while being sewn; this screw, however, will seldom, if ever, be necessary if the spring is sufficiently strong; *g* is an eye or ring fixed to the movable jaw, through which the end of a lever, *h* in *fig.* 908, passes; this lever is connected by a spring to a treadle *i*, at the base of the pedestal, and by the pressure of the right foot upon this treadle, the movable jaw is withdrawn; so that the person employed in sewing may shift the leather, and place another part of the glove between the jaws. The pieces called indexes are connected to the upper part of the jaws, by screws passing through elongated holes which render them capable of adjustment.



The patentee states, that in addition to the index described in his former patent, which is applicable to what is called round-seam sewing only, and which permits the leather to expand but in one direction, when the needle is passed through it, namely, upwards, he now makes two indexes of different construction, one of which he calls the receding index, and the other the longitudinally grooved index. *Fig.* 911 represents an end view, and *fig.* 912, a top view of the receding index, which is particularly adapted for what are called "drawn sewing, and prick-seam sewing." This index, instead of biting to the top, is so rounded off in the inside from the bottom of the cross grooves, as to permit the needles, by being passed backwards and forwards, to carry the silk thread on each side of the leather without passing over it. *Fig.* 913 represents an end view of the longitudinally grooved index, partly open, to show the section of the grooves more distinctly; and *fig.* 914 represents an inside view of one side of the same index, in which the longitudinal groove is shown, passing from *k* to *l*. This index is more particularly adapted to round-seam sewing, and permits the leather to expand in every direction when the needle is passed through it, by which the leather is less strained, and the sewing consequently rendered much stronger.

GLOVE SEWING. The following simple and ingenious apparatus, invented by an Englishman, has been employed extensively in Paris. The instrument is shown in profile ready for action in *fig.* 915. It resembles an iron vice, having the upper portion of each jaw made of brass, and tipped with a kind of comb of the same metal. The teeth of this comb, only one-twelfth of an inch long, are perfectly regular and equal. Change combs are provided for different styles of work. The vice A A is made fast to the edge of the bench or table B, of the proper height, by a thumb-screw C, armed with a cramp which lays hold of the wood. Of the two jaws composing the machine, the one D is made fast to the foot A A, but the other E is movable upon the solid base of the machine, by means of a hinge at the point F. At I I is shown how the upper brass portion is adjusted to the lower part made of iron; the two being secured to each other by two stout screws. The comb, seen separately in *fig.* 917, is made fast to the upper end of each jaw, by the three screws n, n, n. *Fig.* 916, is a front view of the jaw mounted with its comb, to illustrate its construction.



The lever K corresponds by the stout iron wire I, with a pedal pressed by the

needle-woman's foot, whenever she wishes to separate the two jaws, in order to insert between them the parallel edges of leather to be sewed. The instant she lifts her foot, the two jaws join by the force of the spring G, which pushes the movable jaw E against the stationary one D. The spring is made fast to the frame of the vice by the screw H.

After putting the double edge to be sewed in its place, the woman passes her needle successively through all the teeth of the comb, and is sure of making a regular seam in every direction, provided she is careful to make the needle graze along the bottom of the notches. As soon as this piece is sewed, she presses down the pedal with her toes, whereby the jaws start asunder, allowing her to introduce a new seam; and so in quick succession.

The comb may have any desired shape, straight or curved; and the teeth may be larger or smaller, according to the kind of work to be done. With this view, the combs might be changed as occasion requires; but it is more economical to have sets of vices ready mounted with combs of every requisite size and form.

GLUCINA (*Glucine*, Fr.; *Beryllerde*, Germ.) is one of the primitive earths, originally discovered by Vauquelin in 1797 in the emerald of Limoges; he called it glucina from the sweet taste possessed by its salts. Its existence in several other minerals has since been proved: viz., in cymophane or chrysoberyl, phenacite, euclase, gadolinite, leucophane, &c. Its properties have been comparatively little studied, owing to the tedious and expensive processes required for its preparation. From the circumstance that this earth may probably be employed in the production of gems by artificial methods, it is thought important to describe its peculiarities fully.

GLUCINUM, the metal of Glucina has been obtained by M. H. Debray (*Ann. Chym. et Phys.* xliv. 5), by the following process. Into a wide glass tube are introduced two vessels, one containing chloride of glucinum, and the other sodium, deprived of the greatest part of the adhering naphtha by compression between two sheets of blotting paper. The glass tube is placed in a combustion furnace. It is then traversed by a current of hydrogen, passing from the chloride of glucinum to the sodium. The sodium is not placed in the tube until all the air has been expelled by the hydrogen. The tube is then heated just where the sodium is placed, which by this means is deprived of the last particles of naphtha, and fuses. The chloride of glucinum is then heated. The vapour of chloride driven forwards by the hydrogen arrives over the fused sodium. It then swells up, and the heat generated by chemical action is sufficient to raise the contents of the vessel to redness, which often breaks the vessel if made of porcelain. The operation is ended when the chloride of glucinum sublimes beyond the sodium vessel. When the tube is cool the vessel is withdrawn, and in the place of the sodium a large quantity of a blackish substance is found, composed of common salt and the metal glucinum in brilliant spangles, and sometimes even in globules. This mass is quickly detached and fused in a small crucible, with the addition of some dried common salt, which acts as a flux, and facilitates the union of the globules of metal.

It is a white metal, whose density is 2·1. It may be forged and rolled into sheets like gold. Its melting point is inferior to that of silver. It may be melted in the outer blowpipe flame, without exhibiting the phenomenon of ignition presented by zinc and iron under the same circumstances. It cannot be set on fire in an atmosphere of pure oxygen, but in both cases is covered with a film of oxide, which seems to protect it from further action. It is not acted on by sulphur, but readily combines with chlorine and iodine by the aid of heat.

Silicium unites readily with it, forming a hard, brittle substance, capable of taking a high polish. This substance is always formed when glucinum is prepared in porcelain vessels, the silica being reduced by this metal. After several fusions in such vessels, glucinum may contain as much as 20 per cent. of silicium. Glucinum does not decompose water at the temperature of ebullition, nor even at a white heat.

Sulphuric and hydrochloric acids dissolve it easily, either concentrated or diluted, with the evolution of hydrogen.

Nitric acid, even when concentrated, has, at ordinary temperatures, no action upon it, and dissolves it but slowly when boiling.

Glucinum, though not acted on by ammonia, dissolves readily in caustic potash.

The metal which Wöhler obtained, by igniting chloride of glucinum with potassium in a platinum crucible, differs considerably from that just described; the metal thus obtained being a grey powder, very refractory in the furnace, but combines with oxygen, chlorine, and sulphur much more energetically than the metal described by Debray. The differences arise probably partly from the different state of aggregation, and partly from the contamination of Wöhler's metal with platinum and potassium.

Berzelius effected the solution of the beryl by fusing the finely-powdered beryl with three times its weight of carbonate of potash in a platinum crucible, and

then treating the fused mass with hydrochloric acid; but the swelling up of the mixture of carbonate of potash and beryl at the moment of fusion, prevents large quantities being made at a time. To obviate this, Debray uses lime. The following is the process given by him.

The pulverised emerald is mixed with half its weight of quick-lime in powder; the mixture is then fused in an earthen crucible placed in a wind-furnace; the temperature at which the fusion takes place is much lower than that required for the assay of iron. The glass thus obtained is powdered and moistened with water acidulated with nitric acid, so as to obtain a thick paste, to which is added concentrated nitric acid, taking care to stir the mass, which is converted, in the cold, but better by heat, into an homogeneous jelly; this is evaporated to drive off the excess of acid, then heated so as to decompose the nitrates of alumina, glucina, and iron. It is advisable to raise the temperature at the end of the operation so as to decompose a small portion of the nitrate of lime. The result of this calcination is composed of insoluble silica, alumina, glucina, and sesquioxide of iron, insoluble in water, finally nitrate of lime, and a little free lime. It is boiled with water containing some chloride of ammonium.

The nitrate of lime is rapidly removed by the water, and the lime decomposing the chloride of ammonium is also at length dissolved, with liberation of ammonia. This disengagement of ammonia ceases as soon as all the lime is dissolved, and as it is the surest guarantee of the non-solution of the alumina and glucina, the calcination of the nitrates should be repeated, unless ammonia is liberated under the circumstances just mentioned. The residue of silica, alumina, glucina, and iron is well washed until all the lime is removed, which is known by oxalate of ammonia causing no cloudiness in the washings. The separation of the silica and the earths is easily effected, mere boiling with nitric acid dissolving the alumina, glucina, and iron, and leaving the silica undissolved. The solution of the nitrates of alumina, glucina and iron, is then poured into a solution of carbonate of ammonia, to which a little ammonia has been added. The precipitation of the earths takes place without liberation of carbonic acid, and the glucina at length redissolves in the carbonate of ammonia. The solution of the glucina may be considered complete after seven or eight days' digestion. As the carbonate of ammonia may dissolve a little iron, it is better to add to the solution a a few drops of sulphide of ammonium, which precipitates it completely. The solution is then filtered and boiled to drive off the carbonate of ammonia, when the glucina is precipitated in the state of carbonate.

The carbonate of glucina is a dense white powder, easily washed; it is collected on a filter and dried.

From the carbonate any of the other compounds of glucina may be easily prepared; simple calcination converts it into glucina. A process for the separation of alumina and glucina has been proposed by M. Berthier; it consists in suspending the well washed earths in water, and passing a current of sulphurous acid through them. Their solution is complete. The liquid is then boiled to expel the excess of sulphurous acid, when a dense sub-sulphite of alumina is precipitated, leaving the glucina in solution. Debray found that sometimes in this process the glucina was entirely precipitated with the alumina.

Glucina thus obtained possesses the following properties.

It is a light white powder, without smell or taste. Infusible, but volatilises just as zinc and magnesia. Heat does not harden glucina as it does alumina, but renders it nevertheless insoluble in acids. Boiling concentrated sulphuric acid dissolves it easily, but the action of nitric acid is very feeble when the glucina has been strongly heated. Caustic potash dissolves it readily; and glucina is even capable of expelling the carbonic acid from carbonate of potash; it is again precipitated from its solution in potash by boiling when diluted to a *certain* extent.

Ebelmen has obtained it in hexagonal prisms by submitting a solution of glucina, in fused boracic acid, to a powerful and long-continued heat. It may likewise be obtained in microscopic crystals by a more easy process, which consists in decomposing the sulphate of glucina at a high temperature, in the presence of sulphate of potash; also by calcining the double carbonate of glucina and ammonia. The crystals are separated from the sulphate of potash by washing.

The hydrate of glucina is obtained by precipitating a salt of that base by ammonia. The presence of ammoniacal salts does not hinder the precipitation. When recently prepared it greatly resembles the hydrate of alumina; only it absorbs, by drying in the air, a notable quantity of carbonic acid.

The hydrate of glucina easily loses its water by heat, and becomes then insoluble in carbonate of ammonia, the hydrate when pure being very soluble in it; but its solution is hindered by the presence of alumina, in which case, it is only complete after several hours' digestion. It is also soluble in sulphurous acid and bisulphite of ammonia.

Glucina precipitated from some of its solutions by ammonia, is redissolved by pro-

longed ebullition, but this is observed more especially when precipitated from the oxalate or acetate of glucina.

Chloride of glucinum, is prepared by the same process as the chloride of aluminium, merely substituting glucina for alumina, and at first sight very much resembles it; it is, however, much less volatile than chloride of aluminium, being about as volatile as chloride of zinc. It differs also from chloride of aluminium inasmuch as it is not capable of forming definite compounds with some protochlorides; chloride of aluminium uniting with certain protochlorides forming a series of compounds, fusible at a low temperature, volatile at a red heat without decomposition; and the composition of which is represented by the formula $Al^2Cl^3 + MCl$. The crystals of chloride of aluminium may be called chlorinated spinelles, and are easily obtained, it being only necessary, in order to form the sodium compound of the group, to mix the chloride of aluminium with half its weight of common salt, and distil, one distillation producing it pure, the formula of it being $Al^2Cl^3 + NaCl$. Chloride of glucinum is very soluble in water; it may, however, be obtained in crystals, by allowing its solution to evaporate over sulphuric acid under a bell jar. The presence of a little free hydrochloric acid favours the crystallisation. Thus obtained, this salt is a hydrate, and according to Awdejew its formula is $GlCl + 4HO$. The hydrated chloride of glucinum is decomposed by heat into hydrochloric acid and glucina.

Iodide of glucinum.—This compound presents all the characters of the chloride, only being a little less volatile. The affinity of iodine for glucinum, is not very strong, oxygen decomposing the iodide at the heat of a spirit lamp, liberating iodine and forming glucina.

Glucinum is also capable of combining with fluorine; the double fluoride of glucinum and potassium being formed by pouring a solution of fluoride of potassium into a salt of glucina. It is but little soluble in the cold, and is deposited in the form of brilliant scales.

Sulphate of glucina.—This salt is white, has an acid and slightly sweet taste. It is unalterable in the air at ordinary temperatures but effloresces in dry and warm air. By heat, it first fuses, in its water of crystallisation, then at a red heat is decomposed into sulphurous acid, oxygen, and glucina.

Water at 57·2° F. (14° C.) dissolves about its own weight of this salt; its solubility is increased by heat, and boiling water dissolves an indefinite quantity. The presence of free sulphuric acid or alcohol lessens its solubility.

It loses a portion of its acid in many cases with facility; for instance, we obtain an uncrystallisable tribasic sulphate of glucina, by dissolving carbonate of glucina in a concentrated solution of the sulphate; carbonate of glucina is added until carbonic acid ceases to be liberated at each addition; the liquid filtered and evaporated gives a gummy residue. The very dilute solution of this salt lets fall some glucina, and is changed into a bibasic sulphate, also uncrystallisable.

Sulphate of glucina dissolves zinc with disengagement of hydrogen, forming a bibasic sulphate of glucina and sulphate of zinc. Sulphate of alumina, under the same circumstances, dissolves zinc with liberation of hydrogen, and forms a sulphate of zinc and an insoluble subsulphate of alumina. Taking advantage of this difference, Debray proposed a method (*Ann. Chym. et Phys.* xliv. 26), for the separation of alumina and glucina, but which does not answer for analytical purposes, as chemically pure zinc is only acted on with great difficulty by these sulphates. Sulphate of glucina is formed by dissolving the carbonate in dilute sulphuric acid, the evaporated liquid depositing it on cooling. It is essential to keep the liquid distinctly acid; it assists the crystallisation, and besides, if we were to dissolve the carbonate in it until the liberation of carbonic acid ceased, we should obtain a basic uncrystallisable salt. According to Awdejew the formula of this salt is

$$GlO,SO^3 + 4HO.$$

Double sulphate of glucina and potash.—This salt was discovered by Awdejew; he obtained it while endeavouring to produce the double sulphate of glucina and potash corresponding to common alum (which, had he succeeded, would have been one of the best proofs of the analogy existing between alumina and glucina).

It is obtained in crystalline crusts, by evaporating a solution containing 15 parts of sulphate of glucina to 14 parts of sulphate of potash. The concentration is stopped as soon as the liquid becomes turbid; at the end of a few hours this salt is deposited, which is purified by recrystallisation. It is precipitated as a crystalline powder by the addition of sulphuric acid to the concentrated solution. It is but little soluble in the cold, much more so, though slowly, in hot water. By the action of heat it first fuses in its water of crystallisation, then is decomposed entirely into glucina and sulphate of potash, if the heat is strong and long enough applied. Its composition is represented by the formula

$$GlO,SO^3 + KO,SO^3 + 2HO.$$

Carbonate of glucina.—Glucina is soluble in carbonate of ammonia. When the solution is boiled, carbonate of ammonia is driven off, and a precipitate of carbonate of glucina is formed, the composition of which seems to be

$$3GlO,CO^2 + 5HO;$$

but if we arrest the boiling as soon as the solution becomes turbid, we obtain a solution of a double carbonate of glucina and ammonia, from which, by the addition of alcohol, this salt is deposited in clear crystals. *Double carbonate of glucina and ammonia* is white, very soluble in cold water, but is easily decomposed by hot water, liberating carbonate of ammonia and depositing carbonate of glucina. It is much less soluble in dilute alcohol, and nearly insoluble in absolute alcohol. It is easily decomposed by heat, leaving as a residue pure glucina.

It is also decomposed by exposure to the air after some time. According to Debray the formula of this salt is

$$4GlO,3CO^2HO + 3(NH^4O,CO^2)$$

There also exists a double carbonate of potash and glucina corresponding to this salt, and is prepared by the same process, merely substituting carbonate of potash for carbonate of ammonia; the carbonate of potash, however, takes longer to dissolve the glucina than carbonate of ammonia.

Oxalic acid dissolves glucina but does not yield any crystallisable compounds, except in combination with other oxalates, as the oxalate of potash or ammonia.

These double salts crystallise well and have the following simple composition: –

$$GlO,C^2O^3 + KO,C^2O^3;$$
$$GlO,C^2O^3 + NH^4O,C^2O^3.$$

These salts are obtained by dissolving carbonate of glucina in binoxalate of ammonia or potash in the cold, until carbonic acid ceases to be given off. They decrepitate by the application of heat. The composition of glucina is still undecided; Berzelius regarding it as a sesquioxide, and Awdejew and others as a protoxide. The latter view gives greater simplicity in the formula of its compounds, but glucina has no *decided* analogy to the ordinary class of protoxides, lime and magnesia, &c.—H. K B.

GLUCOSE. The name given to grape and starch sugar by M. Dumas. See SUGAR.

GLUE (*Colle forte*, Fr.; *Leim, Tischlerleim*, Germ.) is the chemical substance gelatine in a dry state. The preparation and preservation of the skin and other animal matters employed in the manufacture of glue, constitute a peculiar branch of industry. Those who exercise it should study to prevent the fermentation of the substances, and to diminish the cost of carriage by depriving them of as much water as can conveniently be done. They may then be put in preparation by macerating them in milk of lime, renewed three or four times in the course of a fortnight or three weeks. This process is performed in large tanks of masonry. They are next taken out with all the adhering lime, and laid in a layer, 2 or 3 inches thick, to drain and dry, upon a sloping pavement, where they are turned over by prongs two or three times a day. The action of the lime dissolves the blood and certain soft parts, attacks the epidermis, and disposes the gelatinous matter to dissolve more readily. When the cleansed matters are dried, they may be packed in sacks or hogsheads, and transported to the glue manufactory at any distance. The principal substances of which glue is made are the parings of ox and other thick hides, which form the strongest article, the refuse of the leather dresser; both afford from 45 to 55 per cent. of glue. The tendons, and many other offals of slaughter-houses, also afford materials, though of an inferior quality, for the purpose. The refuse of tanneries, such as the ears of oxen, calves, sheep, &c., are better articles; but parings of parchment, old gloves, and, in fact, animal skin in every form, uncombined with tannin, may be made into glue.

The manufacturer who receives these materials is generally careful to ensure their purification by subjecting them to a weak lime steep, and rinsing them by exposure in baskets to a stream of water. They are lastly drained upon a sloping surface and well turned over till the quicklime gets mild by absorption of carbonic acid; for, in its caustic state, it would damage the glue at the heat of boiling water. It is not necessary, however, to dry them before they are put into the boiler, because they dissolve faster in their soft and tumefied state.

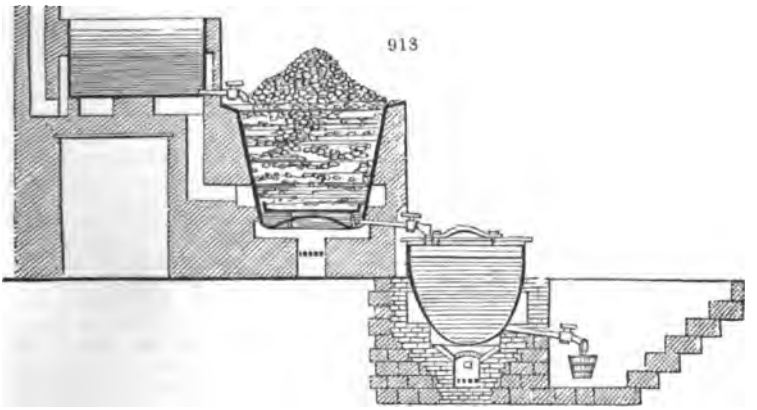
The boiler is made of copper, rather shallow in proportion to its area, with a uniform flat bottom, equably exposed all over to the flame of the fire. Above the true bottom there is a false one of copper or iron, pierced with holes, and standing upon feet 3 or 4 inches high; which serves to sustain the animal matters, and prevent them from being injured by the fire. The copper being filled to two-thirds of its height with soft water, is then heaped up with the bulky animal substances, so high as to surmount its brim. But soon after the ebullition begins they sink down, and, in a few hours, get entirely immersed in the liquid. They should be stirred about from time to time,

and well pressed down towards the false bottom, while a steady but gentle boil is maintained.

The solution must be drawn off in successive portions; a method which fractions the products, or subdivides them into articles of various value, gradually decreasing from the first portion drawn off to the last. It has been ascertained by careful experiments that gelatine gets altered over the fire very soon after it is dissolved, if the heat of 212° is maintained, and it ought therefore to be drawn off whenever it is sufficiently fluid and strong for forming a clear gelatinous mass on cooling, capable of being cut into moderately firm slices by the wire. The point is commonly determined by filling half an egg-shell with the liquor, and exposing it to the air to cool. The jelly ought to get very consistent in the course of a few minutes; if not so, the boiling must be persisted in a little longer. When this term is attained, the fire is smothered up, and the contents of the boiler are left to settle for a quarter of an hour. The stop-cock being partially turned, all the thin gelatinous liquor is run off into a deep boiler, immersed in a warm water bath, so that it may continue hot and fluid for several hours. At the end of this time the supernatant clear liquid is to be drawn off into congealing boxes, as will be presently explained.

The grounds, or undissolved matters in the boiler, are to be again supplied with a quantity of boiling water from an adjoining copper, and are to be once more subjected to the action of the fire, till the contents assume the appearance of dissolved jelly, and afford a fresh quantity of strong glue liquor, by the stop-cock. The grounds should be subjected a third time to this operation, after which they may be put into a bag, and squeezed in a press to leave nothing unextracted. The latter solutions are usually too weak to form glue directly, but they may be strengthened by boiling with a portion of fresh skin-parings.

Fig. 918 represents a convenient apparatus for the boiling of skins into glue, in



which there are three coppers upon three different levels; the uppermost being acted upon by the waste heat of the chimney, provides warm water in the most economical way; the second contains the crude materials, with water for dissolving them; and the third receives the solution to be settled. The last vessel is double, with water contained between the outer and inner one; and discharges its contents by a stop-cock into buckets for filling the gelatinising wooden boxes. The last made solution has about one-five-hundredth part of alum in powder usually added to it, with proper agitation, after which it is left to settle for several hours.

The three successive boils furnish three different qualities of glue.

Flanders or Dutch glue, long much esteemed on the Continent, was made in the manner above described, but at two boils, from animal offals well washed and soaked, so as to need less boiling. The liquor being drawn off thinner, was therefore less coloured, and being made into thinner plates was very transparent. The above two boils gave two qualities of glue.

By the English practice, the whole of the animal matter is brought into solution at once, and the liquor being drawn off, hot water is poured on the residuum, and made to boil on it for some time, when the liquor thus obtained is merely used instead of water upon a fresh quantity of glue materials. The first drawn off liquor is kept hot in a settling copper for five hours, and then the clear solution is drawn off into the boxes.

These boxes are made of deal, of a square form, but a little narrower at bottom than at top. When very regular cakes of glue are wished for, cross grooves of the desired square form are cut in the bottom of the box. The liquid glue is poured into the boxes placed very level, through funnels furnished with filter cloths, till it stands at the brim of each. The apartment in which this is done ought to be as cool and dry as possible, to favour the solidification of the glue, and should be floored with stone flags kept very clean, so that if any glue run through the seams, it may be recovered. At the end of 12 or 18 hours, or usually in the morning if the boxes have been filled over-night, the glue is sufficiently firm for the nets, and they are at this time removed to an upper story, mounted with ventilating windows to admit the air from all quarters. Here the boxes are inverted upon a moistened table, so that the gelatinous cake thus turned out will not adhere to its surface; usually the moist blade of a long knife is insinuated round the sides of the boxes beforehand, to loosen the glue. The mass is first divided into horizontal layers by a brass wire stretched in a frame, like that of a bow-saw, and guided by rulers which are placed at distances corresponding to the desired thickness of the cake of glue. The lines formed by the grooves in the bottom of the box define the superficial area of each cake, where it is to be cut with a moist knife. The gelatinous layers thus formed, must be dextrously lifted, and immediately laid upon nets stretched in wooden frames, till each frame be filled. These frames are set over each other at distances of about three inches, being supported by small wooden pegs, stuck into mortise holes in an upright, fixed round the room; so that the air may have perfectly free access on every side. The cakes must moreover be turned upside down upon the nets twice or thrice every day, which is readily managed, as each frame may be slid out like a drawer, upon the pegs at its two sides.

The drying of the glue is the most precarious part of the manufacture. The least disturbance of the weather may injure the glue during the two or three first days of its exposure; should the temperature of the air rise considerably, the gelatine may turn so soft as to become unshapely, and even to run through the meshes upon the pieces below, or it may get attached to the strings and surround them, so as not to be separable without plunging the net into boiling water. If frost supervene, the water may freeze and form numerous cracks in the cakes. Such pieces must be immediately re-melted and re-formed. A slight fog even produces upon glue newly exposed a serious deterioration; the damp condensed upon its surface occasioning a general mouldiness. A thunderstorm sometimes destroys the coagulating power in the whole laminæ at once; or causes the glue to *turn* on the nets, in the language of the manufacturer. A wind too dry or too hot may cause it to dry so quickly, as to prevent it from contracting to its proper size without numerous cracks and fissures. In this predicament, the closing of all the flaps of the windows is the only means of abating the mischief. On these accounts it is of importance to select the most temperate season of the year, such as spring and autumn, for the glue manufacture.

After the glue is dried upon the nets it may still preserve too much flexibility, or softness at least, to be saleable; in which case it must be dried in a stove by artificial heat. This aid is peculiarly requisite in a humid climate, like that of Great Britain.

When sufficiently dry it next receives a gloss, by being dipped, cake by cake, in hot water, and then rubbed with a brush, also moistened in hot water; after which the glue is arranged upon a hurdle, and transferred to the stove room, if the weather be not sufficiently hot. One day of proper drought will make it ready for being packed up in casks.

The pale coloured, hard, and solid article, possessing a brilliant fracture, which is made from the parings of ox-hides by the first process, is the best and most cohesive, and is most suitable for joiners, cabinet-makers, painters, &c. But many workmen are influenced by such ignorant prejudices, that they still prefer a dark-coloured article, with somewhat of a fetid odour, indicative of its impurity and bad preparation, the result of bad materials and too long exposure to the boiling heat.

There is a good deal of glue made in France from bones freed from the phosphate of lime by muriatic acid. This is a poor article, possessing little cohesive force. It dissolves almost entirely in cold water, which is the best criterion of its imperfection. Glue should merely soften in cold water, and the more considerably it swells, the better, generally speaking, it is.

Some manufacturers prefer a brass to a copper pan for boiling glue, and insist much on skimming it as it boils; but the apparatus represented renders skimming of little consequence. For use, glue should be broken into small pieces, put along with some water into a vessel, allowed to soak for some hours, and subjected to the heat of a boiling-water bath, but not boiled itself. The surrounding hot water keeps it long in a fit state for joiners, cabinet-makers, &c.

Water containing only one-hundredth part of good glue, forms a tremulous solid. When the solution, however, is heated and cooled several times, it loses the property of gelatinising, even though it be enclosed in a vessel hermetically sealed. Isinglass or fish glue undergoes the same change. Common glue is not soluble in alcohol, but is precipitated in a white, coherent, elastic mass, when its watery solution is treated with that fluid. By transmitting chlorine gas through a warm solution of glue, a combination is very readily effected, and a viscid mass is obtained like that thrown down by alcohol. A little chlorine suffices to precipitate the whole of the glue. Concentrated sulphuric acid makes glue undergo remarkable changes; during which are produced sugar of gelatine, leucine, an animal matter, &c. Nitric acid, with the aid of heat, converts glue into malic acid, oxalic acid, a fat analogous to suet, and into tannin; so that, in this way, one piece of skin may be made to tan another. When the mixture of glue and nitric acid is much evaporated, a detonation at last takes place. Strong acetic acid renders glue first soft and transparent, and then dissolves it. Though the solution does not gelatinise, it preserves the property of glueing surfaces together when it dries. Liquid glue dissolves a considerable quantity of lime, and also of the phosphate of lime recently precipitated. Accordingly glue is sometimes contaminated with that salt. Tannin both natural and artificial combines with glue; and with such effect, that one part of glue dissolved in 5000 parts of water affords a sensible precipitate with the infusion of nutgalls. Tannin unites with glue in several proportions, which are to each other as the numbers 1, 1½, and 2; one compound consists of 100 glue and 89 tannin; another of 100 glue and 60 tannin; and a third of 100 glue and 120 tannin. These two substances cannot be afterwards separated from each other by any known chemical process.

Glue may be freed from the foreign animal matters generally present in it, by softening it in cold water, washing it with the same several times till it no longer gives out any colour, then bruising it with the hand, and suspending it in a linen bag beneath the surface of a large quantity of water at 60° F. In this case, the water loaded with the soluble impurities of the glue gradually sinks to the bottom of the vessel, while the pure glue remains in the bag surrounded with water. If this softened glue be heated to 92° without adding water, it will liquefy; and if we heat it to 122°, and filter it, some albuminous and other impurities will remain on the filter, while a colourless solution of glue will pass through.

Experiments have not yet explained how gelatine is formed from skin by ebullition. It is a change somewhat analogous to that of starch into gum and sugar, and takes place without any appreciable disengagement of gas, and even in close vessels. Gelatine, says Berzelius, does not exist in the living body, but several animal tissues, such as skin, cartilages, hartshorn, tendons, the serous membranes, and bones, are susceptible of being converted into it. See GELATINE.

GLUTEN (*Colle Vegetale* and *Gluten*, Fr.; *Kleber*, Germ.) was first extracted by Beccaria from wheat flour, and was long regarded as a proximate principle of plants, till Einhoff, Taddei, and Berzelius succeeded in showing that it may be resolved by means of alcohol into three different substances, one of which resembles closely animal albumine, and has been called *Zymome*, or vegetable albumine; another has been called *Gliadine*; and a third *Mucine*.

Gluten, when dried in the air or a stove, diminishes greatly in size, becomes hard, brittle, glistening, and of a deep yellow colour. It is insoluble in ether, in fat and essential oils, and nearly so in water. Alcohol and acetic acid cause gluten to swell and make a sort of milky solution. Dilute acids and alkaline lyes dissolve gluten. Its ultimate constituents are not determined, but azote is one of them, and accordingly when moist gluten is left to ferment, it exhales the smell of old cheese.

Some years since, M. E. M. Martin, of Vervins, proposed to extract the starch without injuring the gluten, which then becomes available for alimentary purposes. His process is a mechanical one (resembling that long practised in laboratories for procuring gluten), and consists in washing wheat flour, made into a paste, with water, either by the hand or machinery.

The gluten thus obtained is susceptible of numerous useful applications for alimentary purposes. Mixed with wheat flour, in the proportions of 30 parts of flour, 10 of fresh gluten, and 7 of water, it has been employed to produce a superior sort of macaroni, vermicelli, and other kinds of Italian pastes; and MM. Véron Frères, of Paris, have made with it a new sort of paste, which they have termed *granulated gluten* (*gluten granulé*).

GLYCERINE is a sweet substance extracted from fatty substances. It may be prepared in the utmost purity by the following process:—If we take equal parts of olive oil and finely-ground litharge, put them into a basin with a little water, set this on a sand bath moderately heated, and stir the mixture constantly, with the occasional addition of hot water to replace what is lost by evaporation, we shall obtain, in a short

time, a soap or plaster of lead. If, after having added more water to this, we remove the vessel from the fire, decant the liquor, filter it, pass sulphuretted hydrogen through it to separate the lead, then filter afresh, and concentrate the liquor as much as possible without burning, upon the sand-bath, we obtain glycerine; but what remains must be finally evaporated within the receiver of the air-pump. Glycerine thus prepared is a transparent liquid, without colour or smell, and of a syrupy consistence. It has a very sweet taste. Its specific gravity is 1·27 at the temperature of 60°. When thrown upon burning coals, it takes fire and burns like an oil. Water combines with it in almost all proportions; alcohol dissolves it readily; nitric acid converts it into oxalic acid; and, according to Vogel, sulphuric acid transforms it into sugar, in the same way as it does starch. By yeast it becomes acid by the formation of formic and metacetic acids.

Its constituents are, carbon 40, hydrogen 9, oxygen 51, in 100.

Glycerine is one of the products of the saponification of fat oils. It is produced in large quantities in the soap manufactories in a very impure state, being contaminated with saline and empyreumatic matters, and having a very strong disagreeable odour. In order to obtain glycerine from this source, the residuary liquors are evaporated and treated with alcohol, which dissolves out the glycerine. The alcohol having been separated by evaporation, the glycerine is diluted with water, and boiled with animal charcoal. This process must be repeated several times, or until the result is sufficiently free from smell. It is, however, difficult to obtain pure glycerine from this source, on account of the nature and condition of the ingredients usually employed in making soap, which it is almost impossible to deprive of rancid odour.

The compounds of glycerine with the fatty acids constitute the various kinds of fats and oils, but the base does not appear to have the same composition in all. A certain quantity of water appears to separate, and the equivalent of glycerine to be in some fats but half what it is in others. Thus the glycerine of the palm oil has the formula $C^6H^4O^2$, and the glycerine of myristine, or nutmeg butter, C^3H^2O, of which bodies the common glycerine should be the hydrate.

Glycerine is now obtained in great quantities from palm oil, in the process of purification for candles. It is employed with much advantage to preserve soft bodied animals. It is manufactured into soap, is administered internally, and is supposed to possess highly nutritive properties. It has been employed in cases of deafness, and in diseases of the throat. By some it is used to preserve collodion plates in a state of sensitiveness for many days.

GLYPHOGRAPHY. A process introduced some years since to cheapen wood engraving. A metal plate was covered with a thick etching-ground, and an etching made through to the metal in the usual manner. Several coats of ink were then applied by means of a small composition roller. This adheres only to the varnish. When the hollows are deep enough, the plate is placed in connection with a voltaic battery, and copper is deposited in the usual way (see ELECTRO-METALLURGY); the result being a plate with the drawing in relief. The process is rarely practised.

GNEISS may be called stratified, or, by those who object to that term, foliated granite, being formed of the same materials as granite, namely, felspar, quartz, and mica.—*Lyell.*

Gneiss might indeed, in its purest and most typical form, be termed schistose granite, consisting, like granite, of felspar, quartz, and mica; but having those minerals arranged in layers or plates, rather than in a confused aggregation of crystals.—*Jukes.*

In whatever state of aggregation the particles of gneiss may have been originally deposited, we know now that it is a hard, tough, crystalline rock, exhibiting curved and twisted lines of stratification, and composed in the main of quartz, felspar, mica, and hornblende. Mineralogically speaking, it differs from the granite rocks with which it is associated chiefly in this, that while the crystals of quartz, felspar, &c., are distinct and entire in granite, in gneiss they are broken, water-worn, and confusedly aggregated. Hence the general belief is, that gneiss or gneissose rocks are but the particles of granite weathered and worn, carried down by streams and rivers, and deposited in the seas of that early period.—*Page.*

GOBELIN MANUFACTORY. This establishment, which has been long celebrated for its tapestry, took its name from the brothers Gobelin. Giles Gobelin, a dyer at Paris, in the time of Francis I., had found out an improvement in the then usual scarlet dye; and as he had remarked that the water of the rivulet Bievre, in the suburbs of St. Marceau, was excellent for his art, he erected on it a large dye house, which, out of ridicule, was called *Folie-Gobelins* (*Rabelais*). About this period a Flemish painter, whom some name Peter Koek, and others Kloek, and who had travelled a long time in the East, established, and continued to his death in 1550, a manufactory for dyeing scarlet cloth by an improved process. Through the means of Colbert, minister of Louis XIV., one of the Gobelins learned the process used for

preparing the German scarlet dye from one Gluck, whom some consider to be Gulich (who was said to have learned to dye scarlet from one Kuffelar, a dyer at Leyden), and others as Kloek; and the Parisian scarlet dye soon rose into so great repute that the populace imagined that Gobelin had acquired the art from the devil. It is known that Louis XIV., by the advice of Colbert, purchased Gobelin's building from his successors in 1667, and transformed it into a palace, to which he gave the name of *Hotel Royal des Gobelins*, and which he assigned for the use of first-rate artists, particularly painters, jewellers, weavers of tapestry, and others.—*Beckmann.*

The national manufactory is now alone remarkable for its production in textile manufacture of some of the finest works of art; and not only does it excel in the high character of its designs, but also in the brilliancy and permanence of its *colours*.

GOLD. (Eng. and Germ.; *Or*, Fr.) This metal is distinguished by its splendid yellow colour; its great density = 19·3 compared to water 1·0; its fusibility at the 32nd degree of Wedgewood's pyrometer; its pre-eminent ductility and malleability, whence it can be beaten into leaves only 1-282,000th of an inch thick; and its insolubility in any acid menstruum, except the mixture of muriatic and nitric acids,—styled by the alchemists *aqua regia*, because gold was deemed by them to be the king of metals,—or in solutions of chlorine.

Gold is found only in the metallic state, sometimes crystallised in the cube, and its derivative forms. It occurs also in threads of various sizes, twisted and interlaced into a chain of minute octahedral crystals; as also in spangles or rounded grains, which when of a certain magnitude are called *pepitas*. The small grains are not fragments broken from a greater mass; but they show by their flattened ovoid shape and their rounded outline that this is their original state. The spec. grav. of native gold varies from 13·3 to 17·7. Humboldt states that the largest *pepita* known was one found in Peru weighing about 12 kilogrammes (26½ lbs. avoird.); but masses have been quoted in the province of Quito which weighed nearly four times as much. Some of the "nuggets" from Australia have greatly exceeded this.

Another ore of gold is the alloy with silver, or argental gold, the *electrum* of Pliny. It seems to be a definite compound, containing in 100 parts, 64 of gold and 36 of silver.

The mineral formations in which this metal occurs are the crystalline primitive rocks, the compact transition rocks, the trachytic and trap rocks, and alluvial grounds. Sir Roderick Murchison says, in his chapter *On the Original Formation of Gold*, in his "Siluria:"—"We may first proceed to consider the nature and limits of the rich gold-bearing rocks, and then offer proofs, that the chief auriferous wealth, as derived from them, occurs in superficial detritus. Appealing to the structure of the different mountains, which at former periods have afforded, or still afford, any notable amount of gold, we find in all a general agreement. Whether, referring to past history, we cast our eyes to the countries watered by the sources of the Golden Tagus, to the Phrygia and Thrace of the Greeks and Romans, to the Bohemia of the Middle Ages, to tracts in Britain which were worked in old times, and are now either abandoned, or very slightly productive, or to those chains in America and Australia which, previously unsearched, have in our times, proved so rich, we invariably find the same constants in nature. In all these lands, gold has been imparted abundantly to the ancient rocks only, whose order and succession we have traced, or their associated eruptive rocks. Sometimes, however, it is also shown to be diffused through the body of such rocks, whether of igneous or of aqueous origin. The stratified rocks of the highest antiquity, such as the oldest gneiss and quartz rocks (like those, for example, of Scandinavia and the northern Highlands of Scotland), have very seldom borne gold; but the sedimentary accumulations which followed, or the Silurian, Devonian, and carboniferous (particularly the first of these three) have been the deposits which, in the tracts where they have undergone a metamorphosis or change of structure by the influence of igneous agency, or other causes, have been the *chief* sources whence gold has been derived."

Gold is usually either disseminated, and as it were impasted in stony masses, or spread out in thin plates or grains on their surface, or, lastly, implanted in their cavities, under the shape of filaments or crystallised twigs. The minerals composing the veins are either quartz, calcspar, or sulphate of baryta. The ores that accompany the gold in these veins are chiefly iron pyrites, copper pyrites, galena, blende, and mispickel (arsenical pyrites).

In the ores called auriferous pyrites, this metal occurs generally in an invisible form; but though invisible in the fresh pyrites the gold becomes visible by its decomposition; as the hydrated oxide of iron allows the native gold particles to shine forth on their reddish-brown ground, even when the precious metal may constitute only the five millionth part of its weight, as at Rammelsberg in the Hartz. In that state it has been extracted with profit; most frequently by amalgamation with mercury, proving

that the gold was in the native state, and not in that of a sulphuret. The iron pyrites of Wicklow, and of some of our English mines contain gold. After the sulphur of the ore has been separated in the process of manufacturing sulphuric acid, the residuary mass, called "sulphur cake," is roasted with common salt. This is thrown into hot water, the copper which is present, is dissolved as muriate of copper. The silver present has been converted by the roasting process into a chloride; this is dissolved out with a strong brine, from which the silver is precipitated by zinc. The silver cake obtained in this way is sold from prices varying from 6*s.* to 10*s.* the ounce the additional sum above 5*s.* 6*d.* the ounce for pure silver being given for the gold it contains.

Gold exists among the primitive strata, disseminated in small grains, spangles, and crystals. Brazil affords a remarkable example of this species of gold mine. Beds of granular quartz, or micaceous specular iron, in the Sierra of Cocães, 12 leagues beyond Villa Rica, which form a portion of a mica-slate district, includes a great quantity of native gold in spangles, which in this ferruginous rock replace mica.

The auriferous ores of Hungary and Transylvania, composed of tellurium, silver pyrites or sulphuret of silver, and native gold, lie in masses or powerful veins in a rock of trachyte, or in a decomposed felspar subordinate to it. Such is the locality of the gold ore of Konigsberg, of Telkebanya, between Eperies and Tokay in Hungary, and probably that of the gold ores of Kapnick, Felsobanya, &c., in Transylvania; an arrangement nearly the same with what occurs in Equatorial America. The auriferous veins of Guanaxuato, of Real del Monte, of Villalpando, are similar to those of Schemnitz in Hungary, as to magnitude, relative position, the nature of the ores they include, and of the rocks they traverse. These districts have impressed all mineralogists with the evidences of the action of volcanic fire. Breislak and Hacquet have described the gold mines of Transylvania as situated in the crater of an ancient volcano. It is certain that the trachytes which form the principal portions of the rocks including gold, are now almost universally regarded as of igneous or volcanic origin.

It would seem, however, that the primary source of the gold is not in these rocks, but rather in the sienites and greenstone porphyries below them, which in Hungary and Transylvania are rich in great auriferous deposits; for gold has never been found in the trachyte of the Euganean mountains, of the mountains of the Vicentin, or of those of Auvergne; all of which are superposed upon granite rocks, barren in metal.

Finally, if it be true that the ancients worked mines of gold in the island of Ischia, it would be another example, and a very remarkable one, of the presence of this metal in trachytes of an origin evidently volcanic.

Gold is, however, much more common in the alluvial grounds than among the primitive rocks just described. It is found disseminated in the siliceous, argillaceous, and ferruginous sands of certain plains and rivers, especially in their re-entering angles, at the season of low water, and after storms and temporary floods. On the occurrence of gold, Dr. Ure remarks: "It has been supposed that the gold found in the beds of rivers had been torn out by the waters from the veins and primitive rocks, which they traverse. Some have even searched, but in vain at the source of auriferous streams for the native bed of this precious metal. The gold in them belongs, however, to the grounds washed by the waters as they glide along. This opinion, suggested at first by Delius, and supported by Deborn, Guettard, Robitant, Balbo, &c., is founded upon just observations. 1. The soil of these plains contains frequently, at a certain depth, and in several spots, spangles of gold, separable by washing. 2. The beds of the auriferous rivers and streamlets contain more gold after storms of rain upon the plains than in any other circumstances. 3. It happens almost always that gold is found among the sands of rivers only in a very circumscribed space; on ascending these rivers their sands cease to afford gold; though did this metal come from the rocks above, it should be found more abundantly near the source of the rivers. Thus it is known that the Orco contains no gold except from Pont to its junction with the Po. The Ticino affords gold only below the Lago Maggiore, and consequently far from the primitive mountains, after traversing a lake, where its course is slackened, and into which whatsoever is carried down from these mountains must have been deposited. The Rhine gives more gold near Strasburg than near Basle, though the latter be much closer to the mountains. The sands of the Danube do not contain a grain of gold, while this river runs in a mountainous region; that is, from the frontiers of the bishoprick of Passau to Efferding; but its sands become auriferous in the plains below. The same thing is true of the Ems; the sands of the upper portion of this river, as it flows among the mountains of Styria, include no gold; but from its entrance into the plain at Steyer, till its embouchure in the Danube, its sands become auriferous, and are even rich enough to be washed with profit.

The greater part of the auriferous sands, in Europe, Asia, Africa, and America, are black or red, and consequently ferruginous; a remarkable circumstance in the geological position of alluvial gold. M. Napione supposes that the gold of these ferruginous grounds is due to the decomposition of auriferous pyrites. The auriferous sand occurring in Hungary almost always in the neighbourhood of the beds of *lignites*, and the petrified wood covered with gold grains, found buried at a depth of 55 yards in clay, in the mine of Vorospatak near Abrabanya in Transylvania, might lead us to presume that the epoch of the formation of the auriferous alluvia is not remote from that of the lignites. The same association of gold ore and fossil wood occurs in South America, at Moco. Near the village of Lloro have been discovered, at a depth of 20 feet, large trunks of petrified trees, surrounded with fragments of trap rocks interspersed with spangles of gold and platinum. But the alluvial soil affords likewise all the characters of the basaltic rocks; thus in France, the Cèze and the Gardon, auriferous rivers, where they afford most gold, flow over ground apparently derived from the destruction of the trap rocks, which occur *in situ* higher up the country. This fact had struck Reaumur, and this celebrated observer had remarked that the sand which more immediately accompanies the gold spangles in most rivers, and particularly in the Rhone and the Rhine, is composed, like that of Ceylon and Expailly, of black protoxide of iron and small grains of rubies, corundum, hyacinth, &c. Titanium has been observed more recently. It has, lastly, been remarked that the gold of alluvial formations is purer than that extracted from rocks."

Principal Gold Mines.

Spain anciently possessed mines of gold in regular veins, especially in the province of Asturias; but the richness of the American mines caused them to be neglected. Julius Cæsar is said to have paid his enormous debts, and have added largely to the Roman treasury, from the wealth which he derived from the Spanish mines. The Tagus, and some other streams of that country, were said to roll over golden sands. France contains no workable gold mines; but it presents in several of its rivers auriferous sands. There are some gold mines in Piedmont; particularly the veins of auriferous pyrites of Macugnagna, at the foot of Monte Rosa, lying in a mountain of gneiss; and although they do not contain 10 or 11 grains of gold in a hundred-weight, they have long defrayed the expense of working them. On the southern slope of the Pennine Alps, from the Simplon and Monte Rosa to the valley of Aoste, several auriferous districts and rivers occur. Such are the torrent Evenson, which has afforded much gold by washing; the Orco, in its passage from the Pont to the Po: the reddish grounds over which this little river runs for several miles, and the hills in the neighbourhood of Chivasso, contain gold spangles in considerable quantity.

In the county of Wicklow, in Ireland, in the year 1796, some fine specimens of gold were found,—one mass weighing twenty-two ounces. The gold is found in the débris of the valley at the base of Croghan-Kinshela; and it would appear to be derived from the granite of that mountain, or the hornblendic greenstones by which it is traversed. Messrs. Weaver and Mills, however, prosecuted extensive mine workings in search of the source of the gold without any success. As we have already stated, the pyrites of Wicklow contain gold, but no auriferous veins have been discovered. In Cornwall gold has been found in the tin streams of Carnon vale, and some few other spots; and some of the quartz veins traversing the slate have been found to contain gold. Many of the gossans of the copper lodes are known to have gold in them; but it is only in a few rare instances that the precious metal has been separated.

In Devonshire, near North Molton, at the Britannia mine, gold has been found in small quantities, associated with the minerals of the district; but it has never paid the cost of obtaining it. In Scotland also gold has been found. Pennant says: "In the reigns of James IV. and V. of Scotland, vast wealth was procured in the Lead Hills, from the gold washed from the mountains; in the reign of the latter not less than the value of 300,000*l.* sterling." We are told that in another locality a piece of gold weighing thirty ounces was found; but we cannot find any good authority for this statement.

In North Wales, especially in Merionethshire, the older slaty rocks were declared some ten years since to be auriferous. Professor Ramsay has examined and described the district, and especially the mineral and quartz veins of Cwm-eisen-isaf and Doly-frwynog, which contain gold. This district has been worked for gold for some time; but in no case, we believe, to a profit. At Gogofau, not far from Llandovery, the Romans worked for gold, the remains of their workings being still to be discovered. They have been described by Mr. W. Warington Smyth in the Memoirs of the Geological Survey.

There are auriferous sands in some rivers of Switzerland, as the Reuss and the Aar. In Germany no mine of gold is worked, except in the territory of Salzburg, amid the chain of mountains which separate the Tyrol and Carinthia.

The mines of Hungary and Transylvania are the only gold mines of any importance in Europe; they are remarkable for their position, the peculiar metals that accompany them, and their product, estimated at about 1430 pounds avoird. annually. The principal ones are in Hungary, 1, those of Königsberg; the native gold is disseminated in ores of sulphuret of silver, which occur in small masses and in veins in a decomposing felspar rock, amid a conglomerate of pumice, constituting a portion of the trachytic formation; 2, those of Borson, Schemnitz; and 3, of Felsobanya: ores also of auriferous sulphuret of silver occur in veins of sienite and greenstone porphyry; 4, those of Telkebanya, to the south of Kaschau, are in a deposit of auriferous pyrites amid trap rocks of the most recent formation.

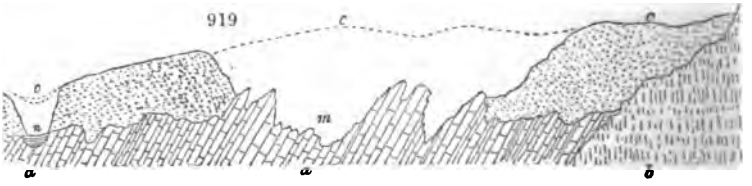
In Transylvania the gold occurs in veins, often of great magnitude. These veins have no side plates or wall stones, but abut, without intermediate gangues, the primitive rock. They consist of decomposing quartz, ferriferous limestone, heavy spar, fluor spar, and sulphuret of silver. The mine of Kapnik deserves notice, where the gold is associated with orpiment, and that of Vorospatak in granite rocks; those of Offenbanya, Zalatna, and Nagy-Ag, where it is associated with tellurium. The last is in sienitic rock on the limits of the trachyte.

In Sweden, the mine of Edelfors in Smoland may be mentioned, where the gold occurs native and in auriferous pyrites; the veins are a brown quartz, in a mountain of foliated hornstone.

In Siberia, native gold occurs in a hornstone at Schlangenberg or Zmeof, and at Zmeino-garsk in the Altai mountains, accompanied with many other ores.

The gold mine of Berezovsk in the Ural mountains has been long known, consisting of *partially decomposed auriferous pyrites*, disseminated in a vein of greasy quartz. This is, according to Murchison, "the only work at which subterranean mining in the solid rock is still practised; there the shaft traverses a mass of apparently metamorphosed and crystalline matrix called '*beresite*,' resembling a decomposed granite with veins of quartz, in which some gold is disseminated." About 1820, a very rich deposit of native gold was discovered on the eastern side of the Ural mountains, disseminated at some yards deep in an argillaceous loam, and accompanied with the *débris* of rocks which usually compose the auriferous alluvial soils, as greenstone, serpentine, protoxide of iron, corundum, &c. The rivers of this district possess auriferous sands.

At the Soimanofsk mines, south of Miask, great piles of ancient drift or gravel having been removed for the extraction of gold, the eroded edges of highly inclined crystalline limestones have been exposed, which, from being much nearer the centre of the chain than the above, are probably of Silurian or Devonian age. It is from the adjacent eruptive serpentinous masses and slaty rocks *b* that the gold shingle *c* (usually most auriferous near the surface of the abraded rock *a*) has been derived.



The tops of the highly inclined beds *a* are in fact rounded off, and the interstices between them worn into holes and cavities, as if by very powerful action of water. Now here, as at Berezovsk, mammoth remains have been found. They were lodged in the lowest part of the excavation, at the spot marked *m*, and at about fifty feet beneath the original surface of overlying coarse gravel *c*, before it was removed by the workmen from the vacant space under the dotted line. The feeble influence of the streams (*n*) which now flow, in excavating even the loose shingle is seen at the spot marked *o*, the bed of the rivulet having been lowered by *human* labour from its natural level *o* to that marked *n* for the convenience of the diggers. — *Murchison.*

It was from the infillings of one of the gravelly depressions between these elevations, south of Miask, that the largest lump of solid gold was found, of which at that time (1824) there was any record. This "pepita" weighs ninety-six pounds troy, and is still exhibited in the museum of the Imperial School of Mines at St. Petersburg.

The quantity of gold raised in Russia during five years was as follows:—

1847	1700	poods.
1848	1660	„
1849	1530	„
1850	1490	„
1851	1266	„
	7646	

Equal to about 296,932 lbs. troy in five years.—*Lectures on Gold, R. Hunt.*

In Erman's "Archives" we find that in the year 1851, the gold of the Uralian washing and amalgamation works produced 332 poods; the Nertschinsk works, 67 poods; the remaining West and East Siberian washings, 1107 poods; the produce of the Altai Mountains and of Nertschinsk Siberian works, 39 poods; making 1546 poods.

In Asia, and especially in its southern districts, there are many mines, streams, rivers, and wastes which contain this metal. The Pactolus, a small river of Lydia, rolled over such golden sands, that it was supposed to constitute the origin of the wealth of Crœsus. But these deposits are now poor and forgotten. Japan, Formosa, Ceylon, Java, Sumatra, Borneo, the Philippines, and some other islands of the Indian Archipelago, are rich in gold streams. Those of Borneo are worked by the Chinese in an alluvial soil on the western coast, at the foot of a chain of volcanic mountains.

Little or no gold comes into Europe from Asia, because its servile inhabitants place their fortune in treasure, and love to hoard up that precious metal.

Numerous gold mines occur on the two slopes of the chain of the Cailas mountains in the Oundès, a province of Little Thibet. The gold lies in quartz veins which traverse a very crumbling reddish granite.

Africa was, with Spain, the source of the greater portion of the gold possessed by the ancients. The gold which Africa still brings into the market is always in dust, showing that the metal is obtained by washing the alluvial soils. None of it is collected in the north of that continent; three or four districts only are remarkable for the quantity of gold they produce.

The first mines are those of Kordofan, between Darfour and Abyssinia. The negroes transport the gold in quills of the ostrich or vulture. These mines seem to have been known to the ancients, who considered Ethiopia to abound in gold. Herodotus relates that the king of that country exhibited to the ambassadors of Cambyses all their prisoners bound with golden chains.

The second and chief exploitation of gold dust is to the south of the great desert of Zaara, in the western part of Africa, from the mouth of the Senegal to the Cape of Palms. The gold occurs in spangles, chiefly near the surface of the earth, in the beds of rivulets, and always in a ferruginous earth. In some places the negroes dig pits in the soil to a depth of about 40 feet, unsupported by any props: they do not follow any vein; nor do they construct a gallery; but by repeated washings they separate the gold from the earthy matters.

The same district furnishes also the greater part of what is carried to Morocco, Fez, and Algiers, by the caravans which go from Timbuctoo on the Niger, across the great desert of Zaara. The gold which arrives by Sennaar at Cairo and Alexandria comes from the same quarter. From Mungo Park's description, it appears that the gold spangles are found usually in a ferruginous small gravel, buried under rolled pebbles.

The third spot in Africa where gold is collected is on the south-east coast, between the twenty-fifth and the twenty-second degree of south latitude, opposite to Madagascar, in the country of Sofala. Some persons think that this was the kingdom of Ophir, whence Solomon obtained his gold.

During the last, and the commencement of the present century, the richest gold mines were found in South America. It occurs there principally in spangles among the alluvial earths, and in the beds of rivers; more rarely in veins.

The gold of Mexico is in a great measure contained in the argentiferous veins, so numerous in that country, whose principal localities are mentioned under the article SILVER. The silver of the argentiferous ores of Guanaxuato contains one 360th of its weight of gold; the annual product of the mines being valued at from 2640 to 3300 pounds avoirdupois.

Oaxaco contains the only auriferous veins explored as gold mines in Mexico; they traverse the rocks of gneiss and mica slate.

All the rivers of the province of Caracas, to ten degrees north of the line, flow over golden sands.

Peru is not rich in gold ores. In the provinces of Huailas and Pataz, this metal is mined in veins of greasy quartz, variegated with red ferruginous spots, which traverse primitive rocks. The mines called *pacos de oro*, consist of ores of iron and copper oxides, containing a great quantity of gold.

All the gold furnished by New Grenada (New Columbia) is the product of washings established in alluvial grounds. The gold exists in spangles and in grains, disseminated among fragments of greenstone and porphyry. At Choco, along with the gold and platinum, hyacinths, zircons, and titanium occur. There has been found, as already stated, in the auriferous localities, large trunks of petrified trees. The gold of Antioquia is 20 carats fine, that of Choco 21, and the largest lump or *pepita* of gold weighed about 27½ pounds avoirdupois. The gold of Chili also occurs in alluvial formations.

Brazil does not contain any gold mine, properly so called; for the veins containing the metal are seldom worked. Dr. Walsh says gold was first known to exist in the Brazils in 1543. The Indians made their fishing-hooks of it, and from them it was discovered that it was found in the beds of streams, brought down from the mountains. But the first ore found by a white man in that country was in the year 1693; this discovery led to the colonisation of the Minas Geräes, and to all those evils resulting from "the cursed lust of gold," with details of which the history of South America abounds.

It is in the sands of the Mandi, a branch of the Rio-Dolce, at Catapreta, that the auriferous ferruginous sands were first discovered in 1682. Since then they have been found almost everywhere at the foot of the immense chain of mountains, which runs nearly parallel with the coast, from the 5th degree south to the 30th. It is particularly near Villa Rica, in the environs of the village Cocães, that the numerous washings for gold are established. The *pepitas* occur in different forms, often adhering to micaceous specular iron. But in the province of Minas Geräes, the gold occurs also in veins, in beds, and in grains, disseminated among the alluvial loams. It has been estimated in annual product, by several authors, at about 2800 pounds avoirdupois of fine metal.

We thus see that almost all the gold brought into the market has come from alluvial lands, and has been extracted by washing.

Californian Gold Mines.—The accident which first revealed the golden treasures of the soil of California, is thus related by a writer in the Quarterly Review, for September, 1852. Captain Suter, the first white man who had established himself in the district where the Americanos joins the Sacramento, having erected a saw-mill on the former river, whose tail race turned out to be too narrow, took out the wheel, and let the water run freely off. A great body of earth having been carried away by the torrent, laid bare many shining yellow spangles, and on examination Mr. Marshall, his surveyor, picked up several little lumps of gold. He and Captain Suter then commenced a search together, and gathered an ounce of the ore from the sand without any difficulty; and with his knife the captain picked out a lump of an ounce and a half from the rock. A Kentuckian workman employed at the mill had espied their supposed secret discovery, and when after a short absence the gentlemen returned, he showed them a handful of the glittering dust. The captain hired a gang of fifty Indians, and set them to work. The news spread, but the announcement of the discovery was received with incredulity beyond the immediate neighbourhood. But presently when large and continuous imports of gold from San Francisco placed the matter beyond doubt, there ensued such a stir in the States, as even in that go-ahead region is wholly without parallel: numbers of every age and of every variety of occupation pushed for the land of promise. Many were accompanied by their families, and most under the excitement of the hour overlooked their physical unfitness, and their inability to procure necessaries. The waters of the Humboldt, from their head to their "sink," a space of nearly 300 miles, are in the dry season strongly impregnated with alkali: and it was here that they first began to faint. Some died from thirst, others from ague, others fell beneath the burdens they attempted to carry when their last animal dropped into the putrid marsh, which grew thicker at every step. Beyond the "sink" the diminished bands had to encounter sixty or seventy miles of desert, where not a blade of herbage grew, and not a drop of pure water could be procured; and those who pushed safely through this ordeal had still to ascend the icy slopes of Sierra Nevada, when the rigours of winter were added to all other difficulties. At different points, one being almost in sight of the golden land, overwearied groups had formed encampments, in case perhaps some help might reach them. It is to the credit of the settlers that on hearing this, they strained their resources to the utmost to afford relief. Yet when all was done, a sick, destitute, most wretched horde of stragglers, was all that remained of the multitude, who, full of hope and spirits, had commenced the prairie journey.

It may be advantageous in this place to determine the difference between the amounts of gold passing into the European markets, before the discoveries of the gold fields of California, and especially of those of Australia, to contrast with the total produce of these countries at the present time.

Table of the quantities of Gold which may be considered as having been brought into the European market, every year on an average, from 1790 *to* 1802.

Continents.	Gold.
ANCIENT CONTINENT.	lbs. Avoir.
Asia: — Siberia	3740
Africa	3300
Europe: — Hungary	1430
Salzbourg	165
Austrian States, Hartz and Hessia, Saxony, Norway, Sweden, France, Spain, &c.	165
Total of the Ancient Continent	8800
NEW CONTINENT.	
North America	2,860
South America: — Spanish dominions	22,000
Brazil	15,400
Total of the New Continent	40,260

The mines of America have sent into Europe three and a half times more gold, and twelve times more silver, than those of the ancient continent. The total quantity of silver was to that of gold in the ratio of 55 to 1; a very different ratio from that which holds really in the value of these two metals, which is in Europe as 1 to 15. This difference depends upon several causes, which cannot be investigated here at length; but it may be stated, that gold, by its rarity and price, being much less employed in the arts than silver, the demand for it is also much less; and this cause is sufficient to lower its price much beneath what it would have been, if it had followed the ratio of its quantity compared to that of silver. Thus also bismuth, tin, &c., though much rarer than silver, are, nevertheless, very inferior in price to it. Before the discovery of America, the value of gold was not so distant from that of silver, because since that era silver has been distributed in Europe in a far greater proportion than gold. In Asia the proportion is now actually only 1 to 11 or 12; the product of the gold mines in that quarter, being not so much below that of the silver mines as in the rest of the world.

The total annual production of gold, exclusive of California and Australia, at present, has been estimated as follows:

From the ancient Spanish colonies of America	10,400 kilogrammes
Brazil	600
Europe and Asiatic Russia	6,200
The Indian Archipelago	4,700
Africa	14,000?
	35,900 = 36 tons nearly,

without taking into account the quantity of gold now extracted from silver.

Report of the production of Gold since its discovery in California,

in	£	in	£
1848	11,700	1853	12,500,000
1849	1,600,000	1854	14,100,000
1850	5,000,000	1855	13,400,000
1851	8,250,000	1856	14,000,000
1852	11,700,000	1857	13,110,000

The history of the production of gold in California and the States of the Union, is well told in the following table, showing the deposits of gold in the limits of the United States. These have been supplied for this work by the obliging kindness of Mr. Rockwell, of Washington.

Statement of Gold of Domestic Production deposited at the Mint of the United States and its Branches, to the close of the Year ending June 30, 1857.

1. Mint of the United States at Philadelphia.

Period.	Virginia.	North Carolina.	South Carolina.	Georgia.	Tennessee.	Alabama.	New Mexico.	California.	Other Sources.	Total.
	Dollars.	Dollars.	Dollars.	Dollars.	Dollars.	Dollars.	Dollars.	Dollars.	Dollars.	Dollars.
1804 to 1827 -	- - -	110,000	- -	- - -	- -	- -	- -	- - -	- -	110,000
1828 to 1837 -	427,000	2,519,500	327,500	1,763,900	12,400	- -	- -	- - -	13,200	5,063,500
1838 to 1847 -	578,294	1,303,636	152,366	566,316	16,499	45,493	- -	- - -	21,037	2,623,641
1848 - -	57,886	109,034	19,228	3,370	3,497	3,670	682	44,177	- -	241,544
1849 - -	129,382	102,688	4,309	10,525	2,739	2,977	32,889	5,481,439	144	5,767,092
1850 - -	65,991	43,734	759	5,114	307	1,178	5,392	31,667,505	226	31,790,306
1851 - -	69,052	49,440	12,338	2,490	126	817	890	46,939,367	- -	47,074,520
1852 - -	83,626	65,248	4,505	3,420	- -	254	814	49,663,623	- -	49,821,490
1853 - -	52,200	45,690	3,522	1,912	- -	- -	3,632	52,732,227	18,748	52,857,931
1854 - -	23,347	9,062	1,220	7,561	- -	245	738	35,671,185	- -	35,713,358
1855 - -	28,295·50	22,626	1,200	1,733·50	- -	310	900	2,634,297·63	1,535	2,691,497·63
1856 - -	21,607	12,910	5,980	4,910	- -	- -	2,460	1,440,134·58	40,750	1,528,751·58
1857 to June 30	2,505	6,805	2,565	3,542	- -	- -	- -	565,566·41	- -	580,938·41
Total - -	1,479,785·50	4,400,373	535,492	2,374,793·50	35,568	254,944	48,397	226,839,521·62	95,740	235,864,614·62

2. Branch Mint, San Francisco.

Period.	California.	Total.
	Dollars.	Dollars.
1854 - - - -	10,842,281·23	10,842,281·23
1855 - - - -	20,860,427·20	20,860,427·20
1856 - - - -	29,209,218·24	29,209,218·24
1857 to June 30 - -	12,526,826·93	12,526,826·93
Total - -	73,438,763·60	73,438,763·60

3. Branch Mint, New Orleans.

Period.	North Carolina.	South Carolina.	Georgia.	Alabama.	California.	Tennessee.	Other Sources.	Total.
	Dollars.	Dollars.	Dollars.	Dollars.	Dollars.	Dollars.	Dollars.	Dollars.
1838–47	741	14,306	37,364	61,903	- -	1,772	3,613	119,699
1848 - -		1,488	2,317	6,717	1,194	947	- -	12,593
1849 - -	- -	- -	- -	4,062	669,921	- -	2,783	677,189
1850 - -	- -	- -	- -	3,560	4,575,576	- -	894	4,580,030
1851 - -	- -	- -	- -	1,040	8,769,682	- -	- -	8,770,722
1852 - -	- -	- -	- -	- -	3,777,784	- -	- -	3,777,784
1853 - -	- -	- -	- -	- -	2,006,673	- -	- -	2,006,673
1854 - -	- -	- -	- -	- -	981,511	- -	- -	981,511
1855 - -	- -	- -	- -	- -	411,517·24	- -	- -	411,517·24
1856 - -	- -	- -	- -	- -	283,344·91	- -	- -	283,344·91
1857 to June 30	- -	- -	- -	- -	129,328·39	- -	- -	129,328·39
Total	741	16,217	39,681	77,282	21,606,461·54	2,719	7,290	21,750,391·54

4. Branch Mint, Charlotte, North Carolina.

Period.	North Carolina.	South Carolina.	California.	Total.
	Dollars.	Dollars.	Dollars.	Dollars.
1838 to 1847 .	1,529,777	143,941	- -	1,673,718
1848 . . .	359,075	11,710	- -	370,785
1849 . . .	378,223	12,509	- -	390,732
1850 . . .	307,289	13,000	- -	320,289
1851 . . .	275,472	25,478	15,111	316,061
1852 . . .	337,604	64,934	28,362	430,900
1853 . . .	227,847	61,845	15,465	305,157
1854 . . .	188,277	19,001	6,328	213,606
1855 . . .	196,894·03	14,277·17	5,817·66	216,988·86
1856 . . .	157,355·18	- -	15,237·35	173,592·53
1857 to June 30 .	75,696·47	- -	- -	75,376·47
Total . . .	4,033,189·68	366,695·17	87,321·01	4,487,205·86

5. Branch Mint, Dahlonega, Georgia.

Period.	North Carolina.	South Carolina.	Georgia.	Tennessee.	Alabama.	California.	Other Sources.	Total.
	Dollars.	Dollars.	Dollars.	Dollars.	Dollars.	Dollars.	Dollars.	Dollars.
1838–47	64,261	95,427	2,978,353	32,175	47,711	- -	- -	3,218,017
1848	5,434	8,151	251,376	2,717	4,075	- -	- -	271,753
1849	4,882	7,323	225,824	2,441	3,661	- -	- -	244,131
1850	4,500	5,700	204,473	1,200	1,800	30,025	- -	247,698
1851	1,971	3,236	154,723	2,251	2,105	214,072	951	379,309
1852	443	57,543	93,122	750	- -	324,931	- -	476,789
1853	2,085	33,950	56,984	149	- -	359,122	- -	452,290
1854	5,818	15,988	47,027	223	- -	211,169	- -	280,225
1855	3,145·82	9,113·27	56,686·36	- -	277·92	47,428·70	- -	116,652·07
1856	- -	25,723·75	44,107·99	106·42	- -	31,467·10	- -	101,405·26
1857 to June 30	- -	8,083·89	25,097·63	- -	- -	6,498·92	- -	39,679·54
Total	92,629·82	270,238·91	4,137,773·98	42,012·42	59,629·92	1,224,712·82	951	5,827,948·87

6. Assay Office, New York.

Period.	Virginia.	North Carolina.	South Carolina.	Georgia.	Alabama.	Tennessee.	California.	Other Sources.	Total.
	Dollars.	Dollars.	Dollars.	Dollars.	Dollars.	Dollars.	Dollars.	Dollars.	Dollars.
1854	167	3,916	395	1,242	- -	- -	9,221,457	- -	9,227,177
1855	2,370	3,750	7,620	13,100	350	- -	25,025,896·11	1600	25,054,686·11
1856	1,928	805·07	4,052·29	41,101·28	233·62	- -	16,529,008·90	- -	16,582,129·16
1857 to June 30	1,531	1,689	2,663	10,451	1,545	- -	9,899,957	- -	9,917,836
Total	10,996	10,160·07	14,730·29	65,894·28	2,128·62	- -	60,676,319·01	1600	60,781,828·27

Summary exhibit of the entire Deposits of Domestic Gold at the United States Mint and Branches from 1804 *to the* 30*th June* 1857.

	Mints.						Total.
	Philadelphia.	San Francisco.	New Orleans.	Charlotte.	Dahlonega.	Assay Office.	
	Dollars.	Dollars.	Dollars.	Dollars.	Dollars.	Dollars.	Dollars.
Virginia - -	1,479,785·56	- -	- -	- -	- -	10,996	1,490,781·56
North Carolina	4,400,373	- -	741	4,033,189·68	92,629·82	10,160·07	8,537,093·57
South Carolina	535,492	- -	16,217	366,695·17	270,238·91	14,730·29	1,203,373·37
Georgia - -	2,374,793·50	- -	3,968	- -	4,137,773·98	65,894·28	6,618,142·76
Tennessee -	35,568	- -	2,719	- -	42,012·42	- -	80,299·42
Alabama - -	54,944	- -	77,282	- -	50,629·9	2,128·62	183,984·54
New Mexico -	49,397	- -	- -	- -	- -	- -	49,397
California -	226,839,521·62	73,438,763·60	21,606,461·54	87,321·01	1,224,712·82	60,676,319·01	383,873,099·60
Other Sources	95,740	- -	7,290	- -	951·	1,600	105,581
Total - -	235,864,614·62	73,438,763·60	21,750,391·54	4,487,205·85	5,827,948·87	60,781,828·27	402,130,792·76

Exports of *gold* and *silver* bullion from the United States, as shown by the annual official reports on "Commerce and Navigation," by the Secretary of the Treasury of the United States. (Prior to 1855, the reports do not show separately the *coin* from the *bullion*, and in the following years *silver* is not separated from *gold*, but almost the entire amount was undoubtedly gold.)

	Dollars.		Dollars.
1855 - -	34,114,995		
1856 - -	28,689,946, of which from S. Francisco,		6,947,404
1857 - -	31,300,980	„	9,922,257

The gold, the production of foreign countries, *imported* into the United States for the years ending 30th June, was as follows: —

Year.	Bullion.	Coin.
1852 - -	$608,257	$3,049,802
1853 - - -	463,044	1,962,312
1854 - - -	1,720,711	1,311,253
1855 - - -	404,217	688,585
1856 - - -	114,289	876,046
1857 - - -	151,585	6,503,051

Shipments of gold from San Francisco colony, to eastern domestic parts and foreign ports, from the San Francisco Price Current: —

	United States.	England.	Other Countries.
1853 - - -	$47,916,447 $\frac{68}{100}$	$4,975,662 $\frac{25}{100}$	$1,913,990.73
1854 - - -	46,289,649 $\frac{78}{100}$	3,781,080 $\frac{71}{100}$	1,163,779,78

Total in 1853 - - - - - - $54,906,100 $\frac{66}{100}$
„ 1854 - - - - - - $51,234,508 $\frac{78}{100}$

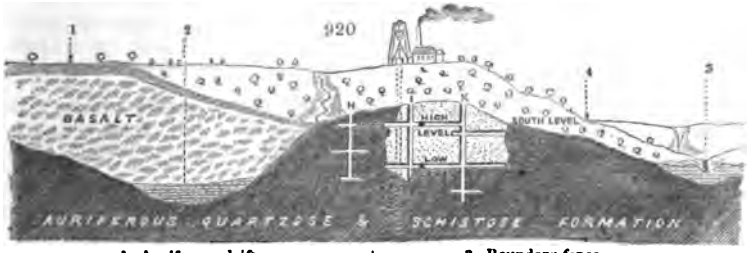
Australian Gold Mines.—The discovery of the great gold field in Australia to the westward of Bathurst, about 150 miles from Sydney, was officially made known in

Great Britain, by a despatch from Sir C. A. Fitzroy to Earl Grey, on the 18th September, 1851, many persons with a tin dish having obtained from one to two ounces per day. On the 25th of May, he writes that lumps have been obtained varying in weight from one ounce to four pounds. On the 29th of May, he writes that gold has been found in abundance, that people of every class are proceeding to the locality, that the field is rich, and from the geological formation of the country, of immense area. By assay the gold is found to consist of 91·1 of that metal and about 8·333 of silver, with a little base metal; or of 22 carats in fineness. July 17th, a mass of gold weighing 106 pounds was found imbedded in the quartz matrix, about 53 miles from Bathurst; and much more, justifying the anticipations formed of the vast richness and extent of the gold field in this colony. This magnificent treasure, the property of Dr. Kerr, surpassed the largest mass found in California, which was 28 pounds; and that in Russia, which was 70 pounds, now in the museum at St. Petersburg. One party of six persons got at the same time 400*l.* in ten days by means of a quicksilver machine; and a party of three, who were unsuccessful for seven days, obtained in five days more than 200 ounces. A royalty of 10 per cent. was ordered to be paid on gold in matrix if found in Crown lands, and 5 per cent. if found in private property.

Numerous claims have been made by persons who have thought that they had given the first indications of gold in Australia. To Sir Roderick Murchison is, however, due the merit of pointing out that gold might probably be found in Australia, long before it was known in Europe that gold existed in that important colony. Sir Roderick Murchison thus gives us the facts: — "Having in the year 1844 recently returned from the auriferous Ural mountains, I had the advantage of examining the numerous specimens collected by my friend Count Strzelecki along the eastern chain of Australia. Seeing the great similarity of the rocks of those two distant countries, I could have little difficulty in drawing a parallel between them; in doing which I was naturally struck by the circumstance that no gold had *yet* been found in the Australian range, which I termed in anticipation the 'Cordillera,' impressed with the conviction that gold would, sooner or later, be found in the great British Colony. I learnt in 1846 with satisfaction that a specimen of the ore had been discovered. I thereupon encouraged the unemployed miners of Cornwall to emigrate, and dig for gold as they dug for tin in the gravel of their own district. These notices were, as far as I know, the first printed documents relating to Australian gold."

August 25th, 1851, Lieutenant-Governor C. J. Latrobe announced to Earl Grey from Melbourne, the discovery of large deposits of gold in that district of the colony. In a second Parliamentary blue book, issued February 3, 1852, it is stated that 79,340 ounces of gold, worth 257,855*l.* 7*s.*, had been previously forwarded to England; and that the gold fields of the colony of Victoria rival, if they do not exceed in value, the first discovered gold fields of New South Wales; the total value being then 300,000*l.*; and but a little time afterwards about half a million sterling. Mr. E. Hargraves, commissioner for Crown lands, announced from Bathurst, that no part of California which he had seen has produced gold so generally and to such an extent as Summerhill Creek, the Turon River, and its tributaries.

For the purpose of conveying a correct idea of the conditions under which the greatest quantity of the Australian gold occurs, three plans have been selected from different districts. The first of these (*fig.* 920) represents a longitudinal section



1 Auriferous drift.
2. Boundary of workings.
3. Boundary fence.
4. Creswick's Creek.

along the course of the west quartz vein in the Clunes gold-mining field. We have here, as indicated by the darker portions of the wood-cut, the quartz vein shown in section, with the shafts sunk, and the levels driven upon it. The lighter portions of the figure resting on the quartzose rock is an auriferous drift; and on the left of the section the great basaltic formation is shown.

Fig. 921 is a section of a portion of the Ballarat gold-field. It is an east and west section from the Red Streak-lead across Post-office Hill, White Flat, the township of

Ballarat West, and the quartz reef west of the township; and it shows the auriferous drift, schist, quartz, and basalt formations of the district.

921

1. The town of Ballarat East.
2. The main road.
3. The Red Streak-lead.
4. The creek.
5. Old Post-office Hill, with quartz reef.
6. Basalt escarpment south of Golden Point.
7. White flat recent auriferous alluvial deposit.
8. Yarrowee Creek.

9 and 11 are two shafts sunk into the ancient auriferous alluvial deposit.

10. The Gravel-Pits lead.
12. Quarts reef beyond the town of Ballarat West, shown in the drawing.

B is the remains of a lava stream, interrupted by the schist and clay slate hills.

D D is the gravel strata which invariably rests on the side of the schist hills which surround the Ballarat basin.

In those two sections we have, therefore, all the conditions shown of the processes of mining on the quartz lodes and in the alluvial deposits.

922

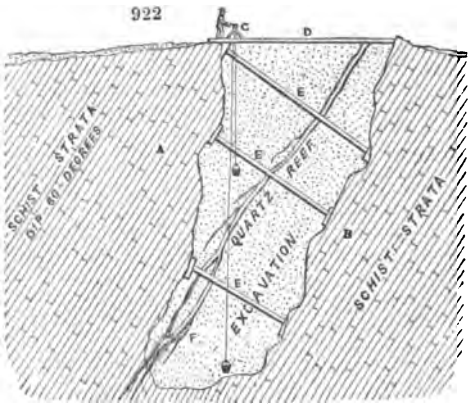


Fig. 922 is a section from the Boroondara and Bulleen gold mines, a few miles from the capital of Victoria. It is the east and west section of the Carlton Estate quartz reef, and is mainly given to illustrate the unskilful and dangerous condition of many of the workings undertaken by men who have no experience in subterranean operations. The shaft, if such it can be called, is about 40 feet deep; and the reef dips with the solid strata at an angle of about 60 degrees to the horizon.

The wall of the shaft at A is not supported on the footwall by props and proper timbering, which it should be, as indicated by E E E. The windlass at C and the frame-work at D are both exceedingly insecure. This is the mode of proceeding in a very important working, where almost every piece of quartz broken out contains gold, and also antimony and iron. At the point F the quartz reef was exceedingly rich, and there it branches off into small strings, yielding 22 ounces of gold to the ton.

It is not necessary here to trace the progress of gold-mining in this colony. The quantity of gold discovered and exported has been enormous. Some exceedingly large "nuggets" have been found; one in Forest Creek, weighing 27 lbs. 6 oz. 15 dwts. and the Welcome Nugget, weighing 2217 oz. 16 dwts.

The produce of the gold fields of Victoria in 1856 was as follows:—

The quantities brought to Melbourne and Geelong by escort,	Oz.
From Castlemain and out-stations - - - - -	372,897
„ Sandhurst and do. - - - - -	599,100
„ Maryborough and do. - - - - -	327,709
„ Ballarat and do. - - - - -	1,009,822
„ Beechworth and do. - - - - -	334,709
	2,644,237
Brought by private hand - - - - -	824,322
Quantity which has evaded duty - - - -	59,411
In the treasury banks at camp, &c., and in transitu -	419,190
Total - - -	3,947,160 oz.

The *exports* of gold from Australia since 1851 have been as follows :—

	Value. £		Value. £
1851 - -	907,113	1855 - -	11,513,230
1852 - -	9,735,903	1856 - -	12,740,480
1853 - -	10,445,700	1857 - -	11,764,299
1854 - -	9,028,759		

The quantities of gold *exported* from New South Wales alone in the same periods have been :—

	Quantities. ozs. dwts. grs.	Value. £ s. d.
1851 - - -	144,120 17 16	468,336 0 0
1852 - - -	818,751 18 17	2,660,946 0 0
1853 - - -	548,052 19 21	1,781,172 0 0
1854 - - -	237,910 13 23	773,209 0 0
1855 - - -	64,384 14 3	209,250 0 0
1856 - - -	42,463 17 1	138,006 0 0
1857 to 31st March -	17,088 8 0	64,081 10 0
	1,872,773 9 9	6,095,000 10 0

The remainder being the produce of the gold fields of Victoria.

Gold has been discovered in some considerable quantities in Tasmania. It has been reported as having been found, although as yet not to any great extent, in New Zealand ; and it is well known that this precious metal is found in all the islands of the eastern Archipelago.

The recent discoveries of Gold in British Columbia.—The following communication from a correspondent to the *Victoria Gazette*, Vancouver's Island, is especially interesting. It is dated *Upper Fraser River*, Nov. 28, 1858.

Magnitude of the Gold-fields of British Columbia.—"That the auriferous deposits of this region are spread over a considerable scope of country is apparent from the fact that paying diggings have already been found on the Fraser River, extending from Fort Hope almost to Fort Alexander, a continuous distance of nearly 400 miles. Among the tributaries of this stream, Thompson and Bridge rivers are known to be auriferous—the latter sufficiently so to have already richly rewarded those who have laboured upon it as high up as 35 or 40 miles from its mouth, while the former has been ascertained to have many bars that will pay in its bed. On two of its confluents — Nicholas and Bonaparte Rivers—good diggings are reported to have been recently discovered. How many more of the numerous branches of these streams shall yet be found abounding in gold remains to be seen, little or no prospecting having thus far been done upon them. Nor is the extent of this gold-field likely to be limited to these rivers and their sources. Coarse gold was found about six weeks since by some packers while exploring for a mule route around Lake Seton. It was discovered on a large creek flowing into the outlet of the lake at a point about 15 miles from the Fraser. The dust was apparently of high standard value: at two places on the Lillooet River bars having been found that will warrant working with a sluice. The first of these is on the east side of the stream, 10 miles above Port Douglas, where a party are now washing with sluices with very satisfactory results. When I passed the spot they had been at work but two days ; the first day three men took out $14 50c., the next day, $18. They showed me the gold, which was fine, like that found on the Lower Fraser. The other bar is 20 miles above Port Douglas. It is very extensive, and promises to pay as well as the one first named, though it has not yet been worked. Bars similar to these are abundant on the Lillooet, and the fact of these having been prospected was owing to the accident of a log cabin having been built near them, and not because they seemed more likely to contain gold than the others, For 100 miles above the Pavilion, and beyond what is termed the Canoe Country, the banks of Fraser River have been proved to pay even better than below, the gold being coarser and more easily saved, as well as more plentiful. It will thus be seen that the gold-fields of British Columbia, ascertained to be paying, to say nothing of rumoured discoveries beyond, are tolerably extensive. They do not, it is true, rival those of California or Australia in magnitude; but that they cover a large scope of country, and will give employment to a large population, is settled beyond controversy or question."

Richness of the Mines.—"To claim that the Fraser River mines are as rich, or that

labour has been generally as well rewarded in them as in the mines of California at an early day, would be idle. I might say much in explanation of the numerous failures that attended the first adventurers to these mines, without making myself their apologist—how the miners came too soon and in too great numbers—how the river kept up, and of the many disadvantages under which they laboured; all might be enlarged upon were it not now well known to the public. In regard to this section, however, I may say those pioneers who worked here last winter and spring uniformly made large wages; and that those who came in since have been able to remain, paying the enormous prices they have done for provisions, proves that they must have had good paying claims most of the time. The cost of living here, with other necessary expenditures, could not have been less than $4 a day to the man, yet I find all have been able to defray their current expenses, while many have accumulated large sums—sufficiently large in a majority of cases, with those who have been here any length of time, to lay in a winter's stock of provisions, even at the present high prices. That better average wages can be made here than in any part of California at present there is no doubt. This can be done even with the present want of ditches and indifferent appliances for taking out the gold. These diggings, owing to the fineness of the dust and the difficulty of saving it, require to be worked with sluices — a mode that has been introduced to but a limited extent as yet, owing to the want of lumber, as well as of wheels or ditches for supplying water. When sluices shall have been generally brought into use, more than twice the amount now realised can be taken out to hand. Another cause that will tend to render these mines highly remunerative in the aggregate is, that every man will be able to secure a claim, and that but little capital will be required for starting operations; hence every one will enjoy the full fruits of his own labour, and none need remain idle. For this winter, owing to the lateness with which provisions have been got in, not much will be done; no one here expects it; the utmost that will be aimed at, as a general thing, will be to make enough to pay expenses of living, to prospect a little, and be on hand at the breaking up of winter. With the coming of spring large operations will be entered into, and all here entertain the most sanguine anticipations, or rather, I should say, fullest confidence as to the results."

Their durability. — "That these mines will be found not only rich and extensive, but also lasting, I am fully satisfied. Apart from their vast extent of surface, the diggings at one time thought to be shallow, are now known to run downward in many localities to a good depth. It has lately been ascertained that not only the bars along the river, but many of the lower benches or table lands contain sufficient gold to pay where water can be brought upon them, which in most cases can easily be done. These benches are not only numerous, but often of great extent, and would afford employment for a large number of men for many years to come. Little or no search has been made as yet for drift diggings or quartz, though there are abundant indications that both, of a paying character, exist. Fine ledges of quartz, in fact, present themselves almost everywhere, though no thorough examination has been made of their quality. The banks of Bridge River consist of alternate strata of slate and quartz rock, the most favourable possible geological formation for gold. I would venture, then, after having seen considerable of the mines in this quarter, to express the confident opinion that they will prove sufficiently extensive, productive, and lasting to warrant a large immigration to this country in the ensuing season, and that British Columbia is destined to become another great gold-producing region, ranking next to California and Australia in the amount she will hereafter annually yield of this precious commodity."

Such is a general view of the gold producing districts of the world. Much fear has been expressed least the influx of gold should reduce the value of that metal. Since the discovery of the Californian gold-field in 1848, not less than £159,807,184 sterling has been added to the wealth of Europe and America from the great gold-fields of California and Australia. This question cannot be discussed in this place, but it is one of the greatest interest, demanding alike the consideration of the politician and the social philosopher.

GOLD BEATING. This is the art of reducing gold to extremely thin leaves, by beating with a hammer. The processes employed for this purpose may be applied to other metals, as silver, platinum, and copper. The Romans used to gild the ceilings and walls of their apartments; and Pliny tells us, that from an ounce of gold forming a plate of 4 fingers square, about 600 leaves of the same area were hammered. At the present day, a piece of gold is extended so as to cover a space 651,590 times greater than its primary surface when cast.

The gold employed in this art ought to be of the finest standard. Alloy hardens gold and renders it less malleable; so that the fraudulent tradesman who should attempt to debase the gold, would expose himself to much greater loss in the operations, than he could derive of profit from the alloy.

Four principal operations constitute the art of gold beating:—

1. The casting of the gold ingots.
2. The hammering.
3. The lamination.
4. The beating.

1. The gold is melted in a crucible along with a little borax. When it has become liquid enough, it is poured out into an ingot-mould previously heated, and greased on the inside. The ingot is taken out and annealed in hot ashes, which both soften it and free it from grease. The moulds are made of cast-iron, with a somewhat concave internal surface, to compensate for the greater contraction of the central parts of the metal in cooling than the edges. The ingots weigh about 2 ounces each, and are $\frac{3}{4}$ of an inch broad.

2. *The forging.*—When the ingot is cold, the French gold-beaters hammer it out on a mass of steel 4 inches long and 3 broad. The hammer for this purpose is called the forging hammer. It weighs about 3 pounds, with a head at one end and a wedge at the other, the head presenting a square face of $1\frac{1}{2}$ inch. Its handle is 6 inches long. The workman reduces the ingot to the thickness of $\frac{1}{8}$ of an inch at most; and during this operation he anneals it whenever its substance becomes hard and apt to crack. The English gold-beaters omit this process of hammering.

3. *The lamination.*—The rollers employed for this purpose should be of a most perfectly cylindrical figure, a polished surface, and so powerful as not to bend or yield in the operation. The ultimate excellence of the gold leaf depends very much on the precision with which the riband is extended in the rolling press. The gold-beater desires to have a riband of such thinness that a square inch of it will weigh $6\frac{1}{2}$ grains. Frequent annealings are requisite during the lamination.

4. *Beating.*—The riband of gold being thus prepared uniform, the gold-beater cuts it with shears into small squares of an inch each, having previously divided it with compasses, so that the pieces may be of as equal weight as possible. The squares are piled over each other in parcels of 150, with a piece of fine calf-skin vellum interposed between each, and about 20 extra vellums at the top and bottom. These vellum leaves are about 4 inches square, on whose centre lie the gold laminæ of an inch square. This packet is kept together by being thrust into a case of strong parchment open at the ends, so as to form a belt or band, whose open sides are covered in by a second case drawn over the packet at right angles to the first. Thus the packet becomes sufficiently compact to bear beating with a hammer of 15 or 16 pounds weight, having a circular face nearly 4 inches diameter, and somewhat convex, whereby it strikes the centre of the packet most forcibly, and thus squeezes out the plates laterally.

The beating is performed on a very strong bench or stool, framed to receive a heavy block of marble, about 9 inches square on the surface, enclosed upon every side by wood-work, except the front, where a leather apron is attached which the workman lays before him to preserve any fragments of gold that may fall out of the packet. The hammer is short-handled, and is managed by the workman with one hand; who strikes fairly on the middle of the packet, frequently turning it over to beat both sides alike; a feat dextrously done in the interval of two strokes, so as not to lose a blow. The packet is occasionally bent or rolled between the hands, to loosen the leaves and secure the ready extension of the gold; or it is taken to pieces to examine the gold, and to shift the central leaves to the outside, and *vice versa*, that everything may be equalised. Whenever the gold plates have extended under this treatment to nearly the size of the vellum, they are removed from the packet, and cut into four equal squares by a knife. They are thus reduced to nearly the same size as at first, and are again made up into packets and enclosed as before, with this difference, that skins prepared from ox-gut are now interposed between each gold leaf, instead of vellum. The second course of beating is performed with a smaller hammer, about 10 pounds in weight, and is continued till the leaves are extended to the size of the skins. During this period, the packet must be often folded, to render the gold as loose as possible between the membranes; otherwise the leaves are easily chafed and broken. They are once more spread on a cushion, and subdivided into four square pieces by means of two pieces of cane cut to very sharp edges, and fixed down transversely on a board. This rectangular cross being applied on each leaf, with slight pressure, divides it into four equal portions. These are next made up into a third packet of convenient thickness, and finally hammered out to the area of fine gold leaf, whose average size is from 3 to $3\frac{1}{2}$ inches square. The leaves will now have obtained an area 192 times greater than the plates before the hammering begun. As these were originally an inch square, and 75 of them weighed an ounce ($= 6\frac{1}{2} \times 75 = 487\frac{1}{2}$), the surface of the finished leaves will be $192 \times 75 = 14{,}400$ square inches, or 100 square feet per ounce troy. This is by no means the ultimate degree of attenuation, for an ounce may be hammered so as to cover 160 square feet; but the waste incident in this case, from the number of broken leaves, and the increase and nicety of the labour, make this an unprofitable

refinement; while the gilder finds such thin leaves to make less durable and satisfactory work.

The finished leaves of gold are put up in small books made of single leaves of soft paper, rubbed over with red chalk to prevent adhesion between them. Before putting the leaves in these books, however, they are lifted one by one with a delicate pair of pincers out of the finishing packet, and spread out on a leather cushion by blowing them flat down. They are then cut to one size, by a sharp-edged square moulding of cane, glued on a flat board. When this square-framed edge is pressed upon the gold, it cuts it to the desired size and shape. Each book commonly contains 25 gold leaves.

We must now describe some peculiarities of the French practice of gold beating. The workman cuts the laminated ribands of an inch broad into portions an inch and a half long. These are called *quartiers*. He takes 24 of them, which he places exactly over each other, so as to form a thickness of about an inch, the riband being $\frac{1}{8}$ of a line, or $\frac{1}{24}$ of an inch thick; and he beats them together on a steel slab with the round face (*panne*) of the hammer, so as to stretch them truly out into the square form. He begins by extending the substance towards the edges, thereafter advancing towards the middle; he then does as much on the other side, and finally hammers the centre. By repeating this mode of beating as often as necessary, he reduces at once all the *quartiers* (squares) of the same packet, till none of them is thicker than a leaf of grey paper, and of the size of a square of 2 inches each side.

When the *quartiers* are brought to this state, the workman takes 56 of them, which he piles over each other, and with which he forms the first packet (*caucher*) in the manner already described; only two leaves of vellum are interposed between each gold leaf. The empty leaves of vellum at the top and bottom of the packet are called *emplures*. They are 4 inches square, as well as the parchment pieces.

The packet thus prepared forms a rectangular parallelopiped; it is enclosed in two sheathes, composed each of several leaves of parchment applied to each, and glued at the two sides, forming a bag open at either end.

The block of black marble is a foot square at top, and 18 inches deep, and is framed as above described. The hammer used for beating the first packet is called the flat, or the enlarging hammer; its head is round, about 5 inches in diameter, and very slightly convex. It is 6 inches high, and tapers gradually from its head to the other extremity, which gives it the form of a hexagonal truncated pyramid. It weighs 14 or 15 pounds.

The French gold-beaters employ besides this hammer, three others of the same form; namely, 1. The *commencing hammer*, which weighs 6 or 7 pounds, has a head 4 inches in diameter, and is more convex than the former. 2. The *spreading hammer*, (*marteau à chasser*); its head is two inches diameter, more convex than the last, and weighs only 4 or 5 pounds. 3. The *finishing hammer*; it weighs 12 or 13 pounds, has a head four inches diameter, and is the most convex of all.

The beating processes do not differ essentially from the English described above. The vellum is rubbed over with fine calcined Paris plaster, with a hare's foot. The skin of the gold-beater is a pellicle separated from the outer surface of ox-gut; but before being employed for this purpose, it must undergo two preparations. 1. It is sweated, in order to expel any grease it may contain. With this view, each piece of membrane is placed between two leaves of white paper; several of these pairs are piled over each other, and struck strongly with a hammer, which drives the grease from the gut into the paper.

2. A body is given to the pieces of gut; that is, they are moistened with an infusion of cinnamon, nutmeg, and other warm and aromatic ingredients, in order to preserve them; an operation repeated after they have been dried in the air. When the leaves of skin are dry, they are put in a press, and are now ready for use. After the parchment, vellum, and gut membrane have been a good deal hammered, they become unfit for work, till they are restored to proper flexibility, by being placed leaf by leaf, between leaves of white paper, moistened sometimes with vinegar, at others with white wine. They are left in this predicament for 3 or 4 hours, under compression of a plank loaded with weights. When they have imbibed the proper humidity, they are put between leaves of parchment 12 inches square, and beat in that situation for a whole day. They are then rubbed over with fine calcined gypsum, as the vellum was originally. The gut-skin is apt to contract damp in standing, and is therefore dried before being used.

The average thickness of common gold leaf is $\frac{1}{282000}$ of an inch.

GOLD, METALLURGIC TREATMENT OF. The gold found in the sands of rivers, or in auriferous soils, needs not be subjected to any metallurgic process, properly speaking. The gold seekers separate it from the sands, by washing them first upon inclined tables, sometimes covered with a cloth, and then by hand in wooden bowls of a particular form. The methods of working vary in different localities.

The people called Bohemians, Cigans, or Tehinganes, who wash the auriferous sands in Hungary, employ a plank with 24 transverse grooves cut in its surface. They hold this plank in an inclined position, and put the sand to be washed in the first groove; they then throw water on it, when the gold mixed with a little sand collects usually towards the lowest furrow. They remove this mixture into a flat wooden basin, and by a peculiar sleight of hand separate the gold entirely from the sand. The richest of the auriferous ores consist of the native gold quite visible, disseminated in a gangue, but the veins are seldom continuous for any length. The other ores of this district are auriferous metallic sulphides, such as sulphides of copper, silver, arsenic, &c., and particularly iron.

The stony ores are first ground in the stamping mill, and then washed in hand-basins, or on wooden tables.

The auriferous sulphides are much more common, but much poorer than the former ores; some contain only one 200,000th part of gold, and yet they may be worked with advantage, when treated with skill and economy.

The gold of these ores is separated by two different processes; namely, by fusion and amalgamation.

The auriferous metallic sulphides are first roasted; then melted into *mattes*, which are roasted anew; next fused with lead, whence an auriferous lead is obtained, which may be refined by the process of cupellation.

When the gold ores are very rich, they are melted directly with lead, without preliminary calcination or fusion. These processes are however little practised, because they are less economical and certain than amalgamation, especially when the gold ores are very poor.

If these ores consist of copper pyrites, and if their treatment has been pushed to the point of obtaining auriferous rose copper, or even black copper including gold, the precious metal cannot be separated by the process of liquation, because the gold, having more affinity for copper than for lead, can be but partially run off by the latter metal. For these reasons the process of amalgamation is far preferable. This process being the same for silver, we reserve its full description for that metal. See SILVER.

The rich ores in which the native gold is apparent, and merely disseminated in a stony gangue, are directly triturated with quicksilver, without any preparatory operation. As to the poor ores, in which the gold seems lost amid a great mass of iron, sulphide of copper, &c., they are subjected to a roasting process before being amalgamated. This process seems requisite to lay bare the gold enveloped in the sulphurets. The quicksilver with which the ore is now ground seizes the whole of its gold, in however small quantity this metal may be present.

The gold produced by the refining process with lead is free from copper and lead, but it may contain iron, tin, or silver. It cannot be separated from iron and tin without great difficulty and expense, if the proportion of gold be too small to admit of the employment of muriatic acid.

By cupellation with lead, gold may be deprived of any antimony united with it.

Tin gives gold a remarkable hardness and brittleness; a piece of gold, exposed for some time over a bath of red hot tin, becomes brittle. The same thing happens more readily over antimony, from the volatility of this metal. A two-thousandth part of antimony, bismuth, or lead destroys the ductility of gold. The tin may be got rid of by throwing some corrosive sublimate or nitre into a crucible, containing the melted alloy. By the first agent, perchloride of tin is volatilised; by the second, *stannate* of potash forms, which is carried off in the resulting alkaline scoriæ.

Gold treated by the process of amalgamation contains commonly nothing but a little silver. The silver is dissolved out by nitric acid, which leaves the gold untouched; but to make this *parting* with success and economy on the great scale, several precautions must be observed.

If the gold do not contain fully two-thirds of its weight of silver, this metal, being thoroughly enveloped by the gold, is partially screened from the action of the acid. Whenever, therefore, it is known by a trial on a small scale, that the silver is much below this proportion, we must bring the alloy of gold and silver to that standard by adding the requisite quantity of the latter metal. This process is called quartation.

This alloy is then granulated or laminated; and from twice to thrice its weight of sulphuric or nitric acid is to be boiled upon it; and when it is judged that the solution has been pushed as far as possible by this first acid, it is decanted, and new acid is poured on. Lastly, after having washed the gold, some sulphuric acid is to be boiled over it, which carries off a two or three thousandth part of silver, which nitric acid alone could not dissolve. Thus perfectly pure gold is obtained.

The silver held in solution by the sulphuric or nitric acid is precipitated in the metallic state by copper, or in the state of chloride by sea-salt. See ASSAY, METALLURGY.

Gold has less affinity for oxygen than any other metal. When alone, it cannot be

oxidised by any degree of heat with contact of air, although in combination with other oxidised bodies, it may pass in a state of an oxide, and be even vitrified. The purple smoke into which gold leaf is converted by an electric discharge is not an oxide, for it is equally formed when the discharge is made through it in hydrogen gas. There are two oxides of gold; the first or protoxide is a green powder, which may be obtained by pouring, in the cold, a solution of potash into a solution of the metallic chloride. It is not durable, but soon changes in the menstruum into metallic gold, and peroxide. Its constituents are 96·13 metal, and 3·87 oxygen. The peroxide is best prepared by adding magnesia to a solution of the metallic chloride; washing the precipitate with water till this no longer takes a yellow tint from muriatic acid; then digesting strong nitric acid upon the residuum, which removes the magnesia, and leaves the peroxide in the form of a black or dark brown powder, which seems to partake more of the properties of a metallic acid than a base. It contains 10·77 per cent. of oxygen. For the curious combination of gold and tin, called the PURPLE PRECIPITATE OF CASSIUS, see CASSIUS, PIGMENTS.

Gold refining.— The following process has been patented as a foreign invention by Mr. W. E. Newton in January, 1851.

It consists, 1, in reducing argentiferous or any other gold bullion to a granulated, or spongy, or disintegrated molecular condition by fusion therewith of zinc, or some other metal baser than silver, and the subsequent removal of the zinc by dilute sulphuric or other acid; that is, the reducing of the gold bullion to a state to allow of the removal by acids of the silver and other impurities contained therein, so as to fit it for coinage and other purposes without quartation with silver, or any other intermediate process; and 2, in pulverising, by grinding or concussion, gold bullion rendered brittle by union with lead, solder, or other suitable metal, the silver and other impurities being removed by acids in this as in the preceding case, and recovered from the acid solution by any of the known chemical means. This operation, if properly conducted, will produce fine ductile gold in a state of great purity; that is, containing from 98·5 to 99·5 per cent. of pure gold.

GOLD-BEATER'S SKIN. This substance is the peritoneal or serous membrane, separated from the intestinal tube of the ox, and sometimes from other animals; it is attenuated by being beaten with a hammer, and subsequently prepared so as to resist putrefaction.

GOLD, MANNHEIM. A brass composed of from 3 to 4 oz. of zinc to one pound of copper. See BRASS.

GOLD, MOSAIC. A brass of very fine colour used in common jewellery. Hamilton and Parker's patent mosaic gold consists of 16½ ounces of zinc to 16 ounces of copper. It is of a dark colour when first cast, but on dipping assumes a beautiful golden tint. The patentees say, "when cooled and broken all yellowness must cease, and the tinge vary from reddish fawn or salmon colour, to a light purple or lilac, and from that to whiteness. See BRASS ALLOYS.

GOLD OF PLEASURE. A plant cultivated on the continent for its seeds, which yield a fine oil, while its fibres can be employed in the manufacture of sail-cloth, packing, and other coarse articles. It is the *Camelina sativa* of botanists. It has not attracted much attention in this country.

GOLD THREAD, or *spun gold*, is a flatted silver-gilt wire, wrapped or laid over a thread of yellow silk, by twisting with a wheel or iron bobbins. By the aid of a mechanism like the braiding machine, a number of threads may thus be twisted at once by one master wheel. The principal nicety consists in so regulating the movements that the successive volutions of the flatted wire on each thread may just touch one another, and form a continuous covering. The French silver for gilding is said to be alloyed with 5 or 6 pennyweights, and ours with 12 pennyweights of copper in the pound troy. The gold is applied in leaves of greater or less thickness, according to the quality of the gilt wire. The smallest proportion formerly allowed in this country by act of parliament was 100 grains of gold to one pound, or 5760 grains of silver; but more or less may now be used. The silver rod is encased in the gold leaf, and the compound cylinder is then drawn into round wire down to a certain size, which is afterwards flatted in a rolling mill, such as is described under MINT.

The liquor employed by goldsmiths to bring out a rich colour on the surface of their trinkets, is made by dissolving 1 part of sea-salt, 1 part of alum, 2 parts of nitre, in 3 or 4 of water. The pickle or sauce, as it is called, takes up not only the copper alloy, but a notable quantity of gold; the total amount of which in the Austrian empire has been estimated annually at 47,000 francs. To recover this gold, the liquor is diluted with at least twice its bulk of boiling water, and a solution of very pure green sulphate of iron is poured into it. The precipitate of gold is washed upon a filter, dried, and purified by melting in a crucible along with a mixture of equal parts of nitre and borax.

GOLD WIRE, is formed by drawing a cylindrical rod of the metal as pure as may be, through a series of holes punched in an iron plate, diminishing progressively in size. The gold, as it is drawn through, becomes hardened by the operation, and requires frequent annealing.

GOLDEN MARCASITE. A name given at one time to the metal zinc. Albertus Magnus calls it *marchasita aurea*. "This was properly a stone, the metallic particles of which were so entirely sublimated by fire, that nothing but useless ashes remained behind. It contained fixed quicksilver, communicated a colour to metals, on which account it was well known to the alchemists, burned in the fire, and was at length entirely consumed. It was found in various parts, but that at Gaslar was the best, because the copper it contained seemed to have in it a mixture of gold. To give this copper, however, a still greater resemblance to gold, some tin was added to it, by which means it became more brittle. This *marchasita* also rendered copper white as silver. Thus far Albertus. It obtained without doubt the name of *marchasita aurea* because zinc communicates a yellow colour to copper; and for the same reason the Greeks and the Arabians called *Cadmia* golden, or *Aurea*."—*Beckmann.*

GOLDEN SULPHURET OF ANTIMONY. *Stibium Sulphuratum Auranticum.* The pentasulphide of antimony, a golden yellow powder, its formula being SbS^5. See ANTIMONY.

GONG-GONG, or *tam-tam* of the Chinese. A kind of cymbal made of a copper alloy. See COPPER.

GONIOMETER. An instrument employed to measure the angles of crystals. The most perfect instrument is the reflecting goniometer of Wollaston. The angle of the crystal is measured by determining through what angular space the crystal must be turned, so that two rays reflected from two surfaces successively shall have the same direction. A simpler form of the instrument consists merely of a semicircular graduated scale of degrees with a movable and a fixed radius. It is a most important instrument to the scientific mineralogist.

GOSSAN, *a Cornish mining term.* An oxide of iron, mixed with other matters. Gossans are found on the upper portions of lodes, and according to their characters are regarded by the miners as favourable or unfavourable indications. The gossans are probably the result of the slow decomposition of the sulphate of iron from the fluid in which the metalliferous matter, deposited in the lode, has been precipitated, or of the sulphides which may have been previously formed. The *gossans* are frequently very rich in silver, and sometimes they contain gold.

GOSSIPIUM. The cotton-tree. See COTTON.

GOVERNOR. A mechanical arrangement usually attributed to Watt, for regulating the motion of a steam-engine.

GRADUATOR. A vessel employed in vinegar manufacture. See ACETIC ACID.

GRAINS OF PARADISE. The fruit of several zingiberaceous plants; sometimes it is called *Mallaguetta pepper*. Pereira distinguishes between the two, but it appears that they commonly pass for the same in commerce. Grains of paradise are imported in casks, barrels, and puncheons from the coast of Guinea. They are used to give a factitious strength and pungency to beer and cordials.

By 56 Geo. III. c. 58, no brewer or dealer in beer shall have in his possession or use grains of paradise, under a penalty of 200*l.* for each offence: and no druggist shall sell it to a brewer under a penalty of 500*l.* for each offence.

GRAIN TIN. See TIN.

GRANITE, in the common and original acceptation of the term, denotes a rock, composed of felspar, quartz, and mica. It oftentimes contains, in addition to these, some other minerals.

These component minerals of granite, both essential and accidental, are united together by a confused crystallisation, not only mutually penetrating and interfering with each other, but sometimes the small crystals of one are completely enveloped in the large crystals of a different kind of mineral, and it is a very common occurrence for one or even more of these minerals to be developed in large crystals, in a granular basis of the whole, so as to constitute a porphyritic granite. This character is generally imparted by the felspar, and rarely by the quartz or mica.—*Boase.*

The chemical composition of ordinary granite is generally as follows:—

Silica	72·3
Alumina	15·3
Alkalies	7·4
Lime and magnesia and iron	5·0

This rock consists generally of about 40 per cent. of felspar, 30 or 40 per cent. of quartz, and from 10 to 20 per cent. of mica.

The granites of Cornwall have been long celebrated for their exceeding durability. Sir Henry de la Beche thus describes the situation of the workable granites: —

"There is much good granite on Dartmoor, though it is not always sufficiently accessible to be carried long distances: the chief places where it is worked in large quantities and afterwards exported are, Hey or High Tor on the east, and near King Tor on the west. The granite from the former place is conveyed by a tram-road to the Stover canal, down which it is carried in boats, and afterwards down the Teign to Teignmouth, to be shipped for its destination. That from the west side of the moor is conveyed by the Prince's town and Plymouth tram-road to the latter place and shipped.

"The continuation of the Hingston Down granite is worked up the Tamar near New Bridge and exported from Morwellham. A very hard variety is obtained upon the higher part of the Down, and has been employed advantageously for pavements. * * * The chief quarries in the eastern or hard part of the Hensborough mass of granite are those of (the late) Mr. Austin Treffry, up the Par Valley, commonly known as Lostwithiel granite. Extensive quarries are there worked, and the stone is brought to the head of the canal near Pons-mill, upon which it is conveyed to Par harbour, and there shipped. * * * The Carn Menelez mass has furnished the granite most commonly known as Cornish. It is nearly altogether shipped at Penryn, where it is brought variable distances from different quarries in the vicinity, many situated in the parish of Mabe."

Since the above report was written, the quarries at the Cheeswring near Liskeard have been opened, and stone of a beautiful quality is raised and exported in large quantities. The Lamorna quarries have also been worked; the stone obtained from them is of excellent quality, and it can be obtained of almost any size.

The quantity of granite exported from the several ports of Cornwall in 1855, is estimated as being 473,716 feet, or about 35,000 tons, the value of which was at least 75,700*l*. Of Devonshire granites the quantities exported from the eastern and western sides of Dartmoor was probably about 5,000 tons.

The following great works, amongst many others, have been constructed entirely or in part of Cornish granites. The Penryn and Lamorna granites have supplied Portland Break-water; Keyham Docks for the Steam Navy; Commercial Docks, London; the Hull, Great Western, and Birkenhead Docks, and the National Works at Chatham and Portsmouth, together with the Scutari Monument. The plinth for the railings of the British Museum was from the Carnsew quarries, and the towers, including the lodge, for gates, &c., from Constantine. From Lamorna blocks of 12 feet square are readily obtained; these quarries produce about 60,000 feet per annum: some stones have been raised 25 feet in length and 11 feet in diameter.

The Cheeswring granite has been used in the London Docks, Westminster Bridge, the Thames embankment, Rochester Bridge, the Docks at Copenhagen, the Great Basses Lighthouse near the island of Ceylon, and for the tomb of the Duke of Wellington in the crypt of St. Paul's Cathedral. These quarries produce from 8,000 to 10,000 tons of stone per annum, and about a similar quantity is annually shipped from the quarries near Par.

The granites of Scotland are chiefly produced from the county of Aberdeen.

The granite of Aberdeen, especially from the quarries of Dancing Cairn, Rubislaw, and Tyrebagger, is much used in the metropolis for kerb and paving stones; some red granite is also quarried. Around Peterhead the red granite prevails, hence it is usually distinguished as the *Peterhead granite.* The principal quarries are those of Black Hill, four miles west of Peterhead, belonging to the Governors of the Merchant Maiden Hospital of Edinburgh; those on the estates of the Earl of Errol, — at Boddam, — at Longhaven, — at Cairngall and at Rova. The Sheerness Docks were built mostly with stone from these quarries. The Stirling Hill quarries, at Bodham, furnished the pillar of the Duke of York's monument; the Seafield quarries the abacus. The beautiful pillars in the library of the British Museum were obtained from Longhaven; the cost for transport, at the time they were worked, being something almost fabulous, so great were the difficulties attending their removal. The pillars in Fishmongers' Hall are from the Stirling quarries, as are also the bases of the monuments of Pitt and Fox; and the polished pillars of the Carlton Club House, in Pall Mall, are from the quarries near Peterhead.

The granites of Ireland.—The most extensive granite district in Ireland stretches south from Dublin, through the counties of Wicklow and Carlow into Kilkenny; it occurs on the south-eastern coast of Down, and around Newry; the range of the Mourne mountains is granite, which again appears in small and isolated protrusions in Derry and Tyrone, and in Cavan. In the western portion of Donegal there is a large extent of this rock, which here partakes of a gneissose character; and again, in

the west of Galway, granite covers a considerable area. The granite of the Wicklow range is the most extensively used. It varies in its quality, that near Kingston being coarse and hard, while that from Ballyknocken, or Golden Hill, is much finer, and therefore fitted for ornamental work. The granite of Down is of a darker colour and finely crystallised. It is extensively quarried at Newry, and sent by water to the north of Ireland.

The Galway granite is of a reddish colour, containing large crystals of flesh red felspar. That of Mayo is of a dark bluish grey colour, while that of Tyrone is reddish.

The Irish granite averages 170 lbs. per cubic foot, its extreme weights being 143 lbs. and 176 lbs. After 88 hours' immersion in water it was found that a cubic foot of the granite of Newry and Kingston absorbed about a quarter of a pound, that of Carlow nearly two pounds, and the granite of Donegal four pounds of that fluid. These facts are important in connexion with the use of these rocks for building purposes. — *Wilkinson's Practical Geology and Ancient Architecture of Ireland.* — *Sir R. Kane's Industrial Resources of Ireland.*

Granite is worked to a small extent at Shap Fell in Westmoreland, and at Mount Sorrel in Leicestershire. The rocks worked as and called the Grooby granite may perhaps be more properly termed Sienites, in some cases assuming the character of a sienitic granite, in others of a sienitic greenstone. These are worked extensively for "pitching" and for macadamising roads.

GRANULATION, is the process by which metals are reduced to minute grains. It is effected by pouring them, in a melted state, through an iron cullender pierced with small holes, into a body of water; or directly upon a bundle of twigs immersed in water. In this way copper is granulated into bean shot, and silver alloys are granulated preparatory to refining. See METALLURGY.

GRAPE SUGAR. So called from its being produced in the grape. See SUGAR. Its formula is $C^{12}H^{14}O^{14}$.

GRAPHITE (*Plombagine*, Fr.; *Reissblei*, Germ.) is a mineral substance of a lead or iron grey colour, a metallic lustre, soft to the touch, and staining the fingers with a lead grey hue. H = 1 to 2. Spec. grav. 2·08 to 2·45. It is easily scratched, or cut with a steel edge, and affords a black streak, displaying the metallic lustre in its interior. B.B. infusible both alone and with reagents: but burns with great difficulty in the outward flame without flame or smoke, generally leaving a residue of oxide of iron. It consists of carbon in a peculiar state of aggregation, with an extremely minute and apparently accidental impregnation of iron. Graphite, called also plumbago and black lead, occurs in gneiss, mica slate, and their subordinate clay slates and limestones, in the form of masses, veins, and kidney-shaped disseminated pieces. It has been found also among the coal strata, as near Cumnock in Ayrshire. This substance is employed for counteracting friction between rubbing surfaces of wood or metal, for making crucibles and portable furnaces, for giving a gloss to the surface of cast iron, &c. See PLUMBAGO.

GRASS OIL. A fragrant oil which is extracted from a peculiar Indian grass; it is generally called the *grass oil of Nemaur*, and it probably bears a close relation to the spikenard of Scripture.

GRATE, *a mining term.* A metal plate pierced with small holes; it is fixed in front of the stamps in which the ore is pounded, and through the holes the finely divided matter makes its escape.

GRAUWACKE or GREYWACKE. *Grau*, grey; *wacké*, clay. A German name, often adopted by geologists for some of the most ancient fossiliferous strata. The rock is often of a grey colour, hence *grau*, German for *grey*; *wache* being a provincial miner's term.

The Greywacke rocks are stratified or slaty rocks, which may be regarded as bearing the same relation to clay slates that argillaceous sandstones and conglomerates bear to common clay. Argillaceous slate, by including rolled fragments or minute grains of quartz sand, with or without mica, becomes the *grauwache* or *grauwache slate* of Werner. Although at one period the term *grauwacke* or *greywacké* was employed to include the Cambrian and Silurian slates, the term has now nearly dropped out of the geological nomenclature.

GRAVITY. The term usually applied to the action of the earth's gravitation.

GRAVITY, SPECIFIC. The difference in weight between a given mass of any body weighed in air, and the same mass weighed in water, is its specific gravity. For a description of the several methods by which the specific gravity of any body, either solid, fluid, or aeriform, may be determined, we must refer to *Ure's Dictionary of Chemistry*, or to any works treating of the manipulating details of physic or chemistry. The following table may be found useful: —

Table of Specific Gravity.

Metals.				Stones, Earths, &c.			
Names.	Weight, water being 1000.	Number of cubic inches in a lb.	Weight of a cubic inch, in lbs.	Names.	Weight, water being 1000.	Weight of a cubic foot, in lbs.	Number of cubic feet in a ton.
Platina - -	19500	1·417	·7053	Marble, average -	2720	170·00	13
Pure gold - -	19258	1·435	·6965	Granite, ditto -	2651	165·68	13½
Mercury - -	13560	2·038	·4904	Purbeck stone -	2601	162·56	13¾
Lead - -	11352	2·435	·4105	Portland ditto -	2570	160·62	14
Pure silver -	10474	2·638	·3788	Bristol ditto -	2554	159·62	14
Bismuth - -	9823	2·814	·3552	Millstone - -	2484	155·25	14¼
Copper, cast -	8788	3·146	·3178	Paving stone -	2415	150·93	14½
— sheet -	8910	3·103	·3225	Craigleith ditto -	2362	147·62	15
Brass, cast - -	7824	3·533	·3036	Grindstone -	2143	133·93	16¾
— sheet -	8396	3·293	·3037	Chalk, British -	2781	173·81	12¾
Iron, cast - -	7264	3·806	·263	Brick- - -	2000	125·00	17
— bar - -	7700	3·592	·279	Coal, Scotch -	1300	81·15	27½
Steel, soft - -	7833	3·530	·2833	— Newcastle -	1270	79·37	28¼
— hard - -	7816	3·537	·2827	— Staffordshire	1240	77·50	29
Tin, cast - -	7291	3·790	·2636	— Cannel -	1238	77·37	29
Zinc, cast - -	7190	3·845	·26				

GREEN EBONY of Jamaica. This is a wood of a brown green colour. It is derived from the *Amerimnum Ebenus*, and is used in turnery and for marquetry work. — See Marquetry and Parquetry.

GREENHEART. A wood brought from Jamaica and Guiana, the produce of the *Laurus chloroxylon*. It is used in shipbuilding. Bancroft, in his *Guiana*, thus describes it: "The Sipiera or Greenheart tree is in size like the locust-tree, about 60 or 70 feet high; there are two species, the black and the yellow, differing only in the colour of their bark and wood."

GREEN PAINTS. (*Couleurs vertes*, Fr.; *Grüne pigmente*, Germ.) Green, which is so common a colour in the vegetable kingdom, is rare in the mineral. There is only one metal, copper, which affords in its combinations the various shades of green in general use. The other metals capable of producing this colour are, chromium in its sesquioxide, nickel in its hydrated oxide, as well as its salts, the seleniate, arseniate, and sulphate; titanium in its prussiate; and some of the salts of uranium.

Green pigments are prepared also by the mixture of yellows and blues; as, for example, the green of Rinman and of Gellert, obtained by the mixture of cobalt blue and flowers of zinc; that of Barth, made with yellow lake, prussian blue, and clay; but these paints seldom appear in the market, because the greens are generally extemporaneous preparations of the artists.

Mountain green consists of the hydrate, oxide, or carbonate of copper, either factitious or as found in nature.

Bremen or *Brunswick green* is a mixture of carbonate of copper with chalk or lime, and sometimes a little magnesia or ammonia. It is improved by an admixture of white lead. It may be prepared by adding ammonia to a mixed solution of sulphate of copper and alum.

Frise green is prepared with sulphate of copper and sal ammoniac.

Mittis green is an arseniate of copper, made by mixing a solution of acetate or sulphate of copper with arsenite of potash. It is in fact Scheele's green.

Sap green is the inspissated juice of buckthorn berries. These are allowed to ferment for 8 days in a tub, then put in a press, adding a little alum to the juice, and concentrated by gentle evaporation. It is lastly put up in pigs' bladders, where it becomes dry and hard. See Colours, *Table of*.

GREENSAND. The term greensand applies to the strata lying between the Chalk and the Wealden deposits. They are of marine origin, as is denoted by the presence throughout their entire thickness of sea-shells, and are divided into an upper and lower series, separated by a stratum of clay, called Gault (which see). The *Upper Greensand*, which underlies the Chalk Marl, is composed chiefly of calcareous sand in

the lower, and Sandstone and layers of Chert in the uppermost part (see FIRESTONE). The sandstone affords a good and durable building stone. The Chert is well adapted from its toughness for making roads, and the sandy portion, in addition to its usefulness as a component of mortar, furnishes an excellent agricultural soil, from the calcareous matter it contains, in addition to the large percentage of soluble silica entering into its composition, which sometimes amounts to more than 40 per cent. In Sussex, Surrey, and Kent, the land based upon the Upper Greensand is known by the name of malm, and produces the greater part of the hops for which those counties are celebrated. In the neighbourhood of Godstone and Merstham, in Surrey, extensive quarries are driven into the hills, at the base of the chalk downs, for the purpose of procuring the soft and chalky stone which occurs there in the higher portion of the Upper Greensand, for which there is a large demand in London, for cleaning door-steps, and stonework in the fronts of houses, under the name of *hearthstones*. A plentiful supply of pure water is borne up by the impermeable strata, forming the uppermost part of the upper greensand, which finds its way out of the ground near the base of the chalk, and forms the sources of many streams and rivers.

The *Lower Greensand* consists of alternations of sands, sandstones, and clays, which are often very ferruginous, so much so sometimes as to constitute a siliceous ore of iron, as is the case at Seend in Gloucestershire, and Shotover in Oxford. The ferruginous sands form the iron-sand of Dr. Smith. The Lower Greensand, also, contains beds of Fuller's Earth, which are worked at Reigate, and furnishes a durable and useful building stone, known by the name of Kentish Rag, and quarried extensively in the neighbourhood of Maidstone.

The term Greensand, though applied to deposits of considerable thickness, is, in fact, only strictly applicable to certain minor portions of them, which are marked by the presence of minute grains of green silicate of iron (the glauconite of American mineralogists). These impart a colour to the beds in which they occur, which has given the name to the entire formation.—H. W. B.

GREEN SLOKE. *Ulva latissima*, the broad green laver. See ALGÆ.

GREENSTONE. Mineralogically, *greenstone* or diabase is pyroxene with Labradorite or oligoclase. Popularly, the term is applied to varieties of trap. "Greenstone is a dark and heavy blackish-green or brownish rock, consisting of felspar and hornblende; it usually has a crystalline texture, but is sometimes compact." —*Dana*.

GREEN ULTRAMARINE. This is artificially prepared in France and Germany, and employed, instead of the arsenical greens, for printing upon cotton and paper. See ULTRAMARINE.

GREEN VITRIOL. Sulphate of iron.

GRENADA COCUS or GRENADILLO. This wood, imported from the West Indies, is called red ebony by the French cabinet-makers.

GREY DYE. (*Teinture grise*, Fr.; *Graufärbe*, Germ.) The grey dyes, in their numerous shades, are merely various tints of black, in a more or less diluted state, from the deepest to the lightest hue.

The dyeing materials are essentially the tannic and gallic acid of galls or other astringents, along with the sulphate or acetate of iron, and occasionally wine stone or crude tartar. *Ash grey* is given for 30 pounds of woollen stuff, by one pound of gall nuts, ½ lb. of wine stone, and 2½ lbs. of sulphate of iron. The galls and the wine stone being boiled with from 70 to 80 pounds of water, the stuff is to be turned through the decoction at a boiling heat for half an hour, then taken out, when the bath being refreshed with cold water, the copperas is to be added, and, as soon as it is dissolved, the stuff is to be put in and fully dyed. Or, for 36 pounds of wool; 2 pounds of tartar, ½ pound of galls, 3 pounds of sumach, and 2 pounds of sulphate of iron are to be taken. The tartar being dissolved in 80 pounds of boiling water, he wool is to be turned through the solution for half an hour, and then taken out. The copper being filled up to its former level with fresh water, the decoction of the galls and sumach is to be poured in, and the wool boiled for half an hour in the bath. The wood is then taken out, while the copperas is being added and dissolved; after which it is replaced in the bath, and dyed grey with a gentle heat.

If the grey is to have a yellow cast, instead of the tartar, its own weight of alum is to be taken; instead of the galls, one pound of old fustic; instead of the copperas, ¾ of a pound of Saltzburg vitriol, which consists, in 22¾ parts, of 17 of sulphate of iron, and 5¾ of sulphate of copper; then proceed as above directed. Or the stuff may be first stained in a bath of fustic, next in a weak bath of galls with a little alum; then the wool being taken out, a little vitriol (common or Saltzburg) is to be put in, previously dissolved in a decoction of logwood; and in this bath the dye is completed.

Pearl-grey is produced by passing the stuff first through a decoction of sumach and logwood (2 lbs. of the former to 1 of the latter), afterwards through a dilute solution of sulphate or acetate of iron; and finishing it in a weak bath of weld containing a little alum. *Mouse-grey* is obtained when, with the same proportions as for ash-grey, a small quantity of alum is introduced.

For several other shades, as tawny-grey, iron-grey, and slate-grey, the stuff must receive a previous blue ground by dipping it in the indigo vat; then it is passed first through a boiling bath of sumach with galls, and lastly through the same bath at a lower temperature after it has received the proper quantity of solution of iron.

For dyeing silk grey, fustet, logwood, sumach, and elder-tree bark, are employed instead of galls. Archil and annotto are frequently used to soften and beautify the tint.

The mode of producing grey dyes upon cotton has been explained in the articles CALICO PRINTING and DYEING.

GRINDING AND CRUSHING MACHINERY. *Crushing Mill.* This machine was introduced into the mines of Cornwall and Devon in the early part of the present century. In its simplest form it consists of two rollers mounted in a strong iron frame, and kept in contact by means of screws; motion is communicated to one of the rolls, either by a water-wheel or steam-engine, but the other is made to revolve by the friction generated between the moving roll and the stuff to be crushed. This mill is usually employed for reducing mineral substances which have already received some mechanical preparation, but machines have been contrived with a series of rolls, set below each other, into which the stuff is introduced as brought from the lode under-ground. In order to effect this operation, the upper rolls are fluted, and the lower ones have various speeds and diameters, but it may be remarked that although this arrangement has been somewhat extensively employed in the north of England, yet it has found few advocates either in Wales or Cornwall.

The practice of keeping the rolls together by screws acting on the bearings is objectionable, since the entrance of a piece of steel, or other hard substance of greater

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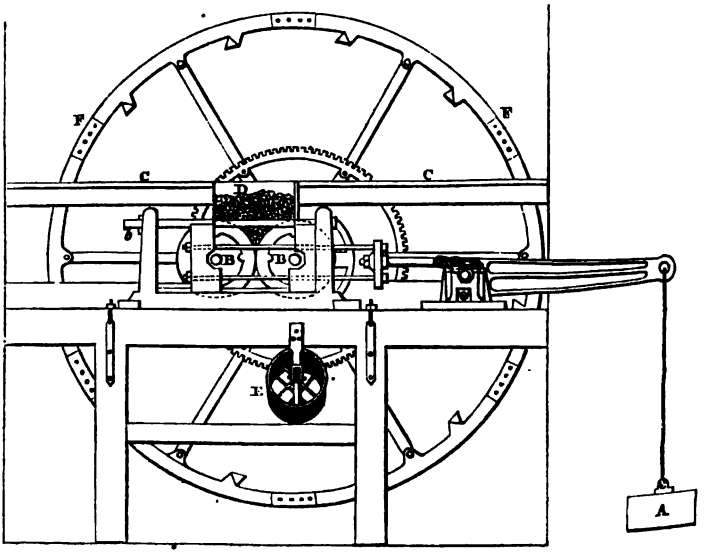


width than the fixed opening between the rolls, immediately produces a stoppage and strains the apparatus, or otherwise causes serious breakages to some of the parts. In order to obviate these evils, the rolls are usually adjusted and kept in position by weighted levers pressing on their axis.

As the machines employed in Cornwall may be considered the most effective in

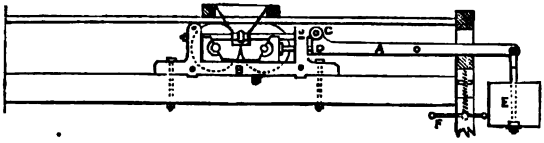
operation as well as complete in their construction, that type is selected for representation.

B B (*fig.* 923), are the crushing rollers fitted in a strong frame-work of cast iron, which is stayed by a wrought iron bar *b*, and firmly bolted to longitudinal beams inserted in the walls of the crushing-house. The rollers revolve in bearings, which are so arranged as to slide in grooves, and therefore admit of the cylinders being brought nearer to or separated farther from each other. To keep the rollers in contact and yet allow the action to take place, a weighted lever A is placed on each side, which by means of tension bars connected with one of the bearings, keeps a constant pressure upon the rollers. The ore to be crushed is lodged upon a floor C, and introduced into a hopper D, from which it falls between the rolls; the requisite crushing pressure being attained by increasing or decreasing the weights applied to the end of the lever. The crushed ore passes from between the rollers B B into the higher extremity of an inclined cylinder E, made of coarse gauze, or perforated plate, which being set in motion by the same power as the rollers themselves, separates the pulverised material into two classes. That portion which passes through the sieve falls into a waggon placed on the floor of the house, whilst the other, which is too large to escape through the openings, is carried to the lower end of the cylinder from whence it passes into an inverted bucket-wheel F, by which it is again conveyed into the hopper to be re-crushed.

The modifications to the foregoing arrangement may be thus briefly noticed.

In some machines the feed hopper is made of sufficient capacity to hold from 20 to

924



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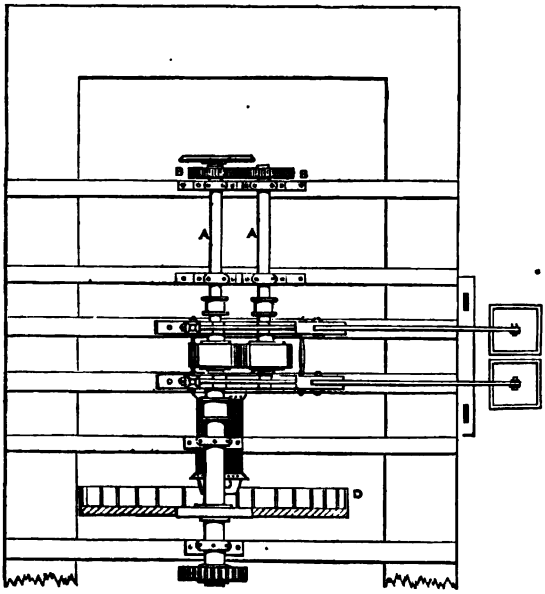


25 cwt. of stuff, which is introduced by means of a tram waggon, and renders hand feeding unnecessary. The shoot conveying the crushed ore to the rotating sieve, E, is sometimes divided at the bottom into two parts, one to deliver rough, and the other

fine stuff. In connection with each division, is a cylindrical riddle revolving and separating the work according to the fineness or coarseness of the mesh employed.

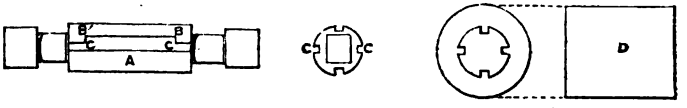
A circular sieve divided midway into two parts, each of a different mesh, is in some instances, advantageously substituted for two sets of sieves; whilst, in other cases, circular sieves are omitted, the operation of sizing being performed by fixing perforated plates on the periphery of the inverted wheel.

Instead of one roll being drawn towards the other, they are more commonly kept in contact by direct pressure, which is effected as shown in *figs.* 924, 925.

A, lever hung to the cast-iron frame B at C, and pressing upon pin at D. When it is required to change the rollers, the pressure resulting from the lever A and weighted box E, is relieved by means of the screw tackle F.

The considerations which should be attended to in constructing a crushing mill, are, first to make all the parts sufficiently strong to meet the varying resistances which continually occur in crushing. For this purpose, the framework to receive the rolls ought to be of good cast iron, the axles of the rollers of best wrought iron, and the cylinders of the hardest and most uniform metal. 2ndly. To design the machine, so that the matter to be crushed may be readily delivered into the hopper, sized by the circular sieves, for the dressing process, and such portions as are not properly crushed, returned to the rolls without the intervention of manual labour. In order to effect this, the inverted, or raff wheel D, *fig.* 925, shown in section, ought to be made of sufficient diameter to allow the stuff, on being discharged, to descend by its own gravity, into the feed-hopper. 3rdly. To extend from the axis of the rollers, long tumbling shafts, A A, *fig.* 925, and fix on their ends the driving wheels B B, allowing a little play in the plummer blocks, so that any undue opening of the rolls may not vary the pitch line of the wheels, B B, to such an extent as to endanger the safety of the teeth. 4thly. To construct the roll so that it may be readily changed, yet maintained on its axis without slipping when in motion. One of the most efficient plans for this purpose, is shown in the following woodcut, in which A is the axis or arbor, and D the roll.

926



It will be seen that the cylinder roll is fitted with four internal projections; these are of the same length as the portion of the groove marked B B', but no wider than the narrower part of the groove C. When the cylinder is to be fixed on the axis, the studs are introduced into the recesses C, and the cylinder advanced into its working position, when it is turned until the studs fit into that portion of the recess between B B', and which are then wedged to the roll by a close-fitting cutter.

5thly. The diameter of the rolls should be *decreased*, and the length *increased* in proportion to the fineness of the stuff to be crushed, since a fine material requires a longer line of contact, and not so large a grip as coarser substances.

In practice it has been found advantageous to make the roller placed on the driving shaft somewhat longer than that which is opposite, and to work the rolls by spur gearing rather than by friction, since the latter is proved to furnish less economical results than the former. It has also been found injudicious to harden the rolls by chilling; hence ordinary sand cast rolls are most frequently employed.

The speed of the rolls varies from 45 to 60 feet per minute, but this necessarily differs with the character of the stuff to be crushed. Again great variation is experienced in the quantities crushed within a given period, since a small amount of moisture in vein stuff of a certain class, makes it cake, and will thus considerably reduce the produce of the mill. On the other hand, if the matter operated upon, be very dry, heavy, and brittle, as in the case of some varieties of lead ore, the produce may be much increased, since the mill can be driven at a great speed; a less bulk will have to pass for a given weight, and there will be a smaller quantity of material carried back by the raff wheel to be recrushed.

Variable speeds have sometimes been tried in order to produce friction together with pressure at the line of contact, but it has been found that any departure from a uniform speed on the two surfaces, absorbs a considerable additional amount of power, without materially augmenting the results.

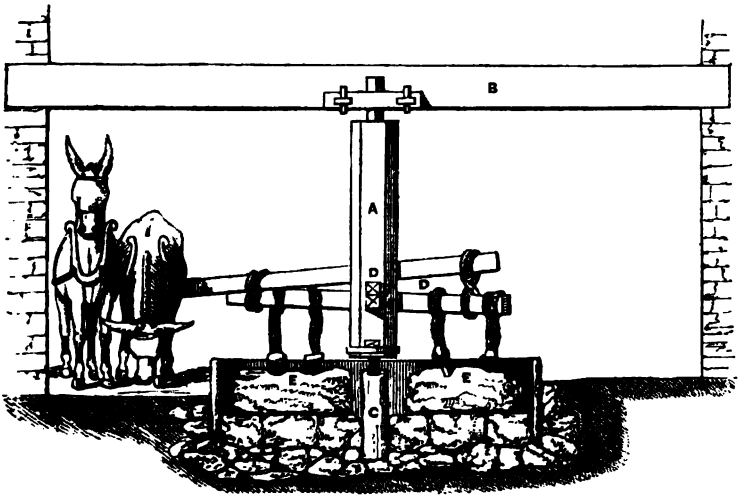
The various dimensions and velocities of the rolls, crushing force, and power employed, effective value of different mills, &c., now in use, may be gathered by referring to the following table:—

Name of Mine.	Rollers.				Total pressing Force on Rolls.	Sifter.				Diameter of Ruff Wheel.	Horse Power.	Quantity of Ruff Crushed in 10 Hours.	Cost of Crushing per Ton.
	Diameter of Roller.	Length of Roller.	No. of Revolutions per Min.	Total Crushing Area per Min.		Diameter of Sifter.	Length of Sifter.	No. of Holes in Sifter.	Revolutions per Minute.				
	In.	In.		Sq. In.	Cwt.	In.	In.	Sq. In.				Tons.	Pence.
Grassington Mines	27	12	5½	5593	91	21	48	6½	37	14·0		80	,,
Minera . .	14	14	6	4920	73½	24	42	9	48	10·6	6	20	2½
Cwmystwith No. 1	27	14	4	4749	78	20	33	9	24	16·0	,,	32	2½
,, No. 2	27	14	4½	5341	85	24	36	9	24	16 0	,,	35	2½
Goginan . .	30	14	5½	7254	39	20	39	9	36	16 0	,,	30	2½
Cwm Erfin . .	27	14	7½	8902	293	26	32	9	30	16 0	,,	20	3
Lisburne No. 1 .	27	15	6	7632	180	22	36	12½	30	16·0	,,	42	2½
,, No. 2 .	27	15	6	7632	224	22	36	12½	30	16·0	,,	42	2½
Derwent . .	27	14	7	8909	227	22	60	16	,,	15·0	,,	60	2½
Goldscope, (2 sets of rolls, 1 fluted, other plain). .	14	18	14	11060	6	No Sifter.				,,	,,	25	2½
East Darren .	30	16	6	9996	207	24	36	16	48	16·0	,,	28	2½
Cefn Cwm Brwynog	30	13	5	4090	84	20	48	16	27½	14·0	,,	20	2½
Lisburne No. 3 .	18	16	8	6432	169	22	36	25	30	16·0	,,	42	2½
Llandudno . .	18	15	15	12705	61	Flat Sifter, 1-16th inch.				Jacob's ladder.	Steam power.	30	11½
Wheal Friendship	22	12	10	8670	123	24	36	36	30	13·0	15	20	2½
Pontgibaud . .	25	12	12½	13075	36	22	44	36	60	15·0	10	17	3½
Devon Great Consols.	24	22	7	16443	456	2 { 24 bar. 12 sm.	84	64	21	,,	,,	65	2½
Fabrica la Constante, Spain, No. 1 . .	24	15	10	11300	147	25	45	100	30	15·0	37	50	3½
,, No. 2 .	27	15	10	12720	110	25	53	100	30	16·0	26	50	3½
,, No. 3 .	24	12	16	14464	84	25	45	3600	48	Jacob's ladder, 192 ft. per m.	37	cwt. 13	19
,, No. 4 .	27	15	15	19080	93	26	58	3600	45	Ditto.	,,	13	19

Arrastre or tahona.—This machine is extensively employed in the mining districts of Mexico, for grinding silver ores previous to their amalgamation.

It consists of a strong wooden axle A (*fig.* 927), moving on a spindle in a beam B above

927



it, and resting on an iron pivot beneath, turning in an iron bearing, which is inserted into a post of wood C, which rises about a foot above the ground in the centre of the arrastre. The shaft A is crossed at right angles by two strong spars D D, which form four arms, each about 5 feet long, one excepted, which is 9 feet long, to admit of two mules being attached to it; by this arm the machine is worked. The grinding is per-

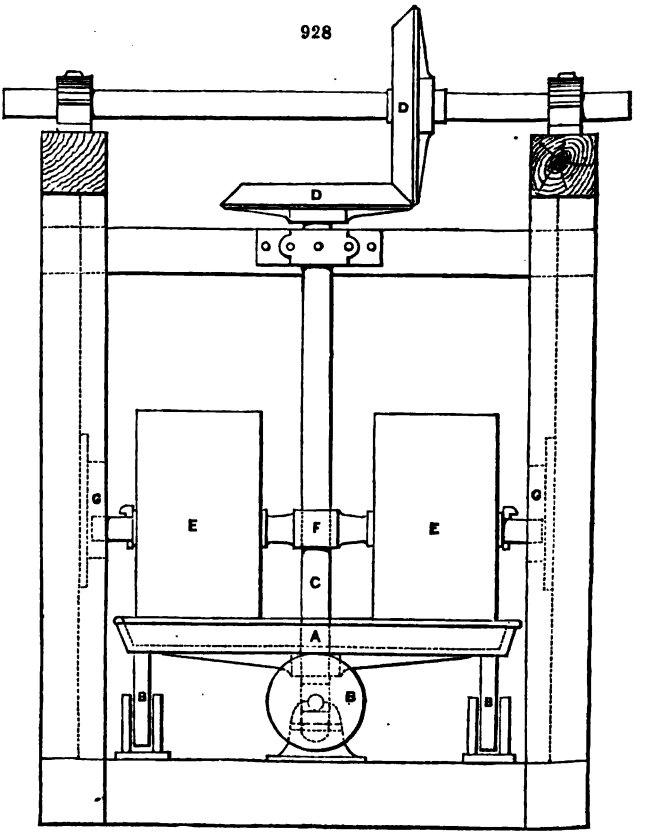
formed by four large porphyritic or basaltic stones, two of which are shown, E E. These are loosely attached by thongs of leather, or small sized rope, to the four arms, and are dragged round over the ore, which is put in with water, until it is ground to a very fine slime or mud, called the *lama*. One of these machines, when in good working condition, will grind from 600 to 800 pounds weight of ore in twenty-four hours. In Guanaxuato, where the best and finest grinding is obtained in the arrastres, the lining or foundation and the grinding stones, are of course, grained porphyry, and form a rough surface. The cost of this apparatus in Mexico, including the paving of the bottom, and the four *metapiles* or stones, is on an average 7*l*. The original weight of a metapile, is about 700 pounds, its dimensions are 2 feet 8 inches long, 18 inches broad, and 18 inches deep. Notwithstanding the hardness of the stones employed, they are so worn as to become unserviceable in the course of ten or twelve weeks; the bottom, however, is only replaced once in twelve months.

This apparatus is well suited to patio amalgamation, but it affords bad results for the power expended.

Edge mill. — This machine is employed for the purpose of reducing gold and silver ores to an impalpable powder. It is also used extensively in grinding flints stones, slags, and a variety of other products. However much the details of this apparatus may vary, its principle is the same in all cases. Two vertical runners rotate on the outer circumference of a flat or slightly conical basin and afford a frictional or grinding area *equal to the difference of distance performed by the inner and outer edges.*

The subjoined woodcut, *fig.* 928, represents a mill constructed at the Mould Foundry,

928



Flintshire. A, rotating pan, resting upon frictional wheels B; C, vertical shaft firmly keyed to pan A, to which motion is communicated by wheel gearing D. The runners E E revolve on arm F, and may be of cast iron or of stone bound with a *ring of iron.*

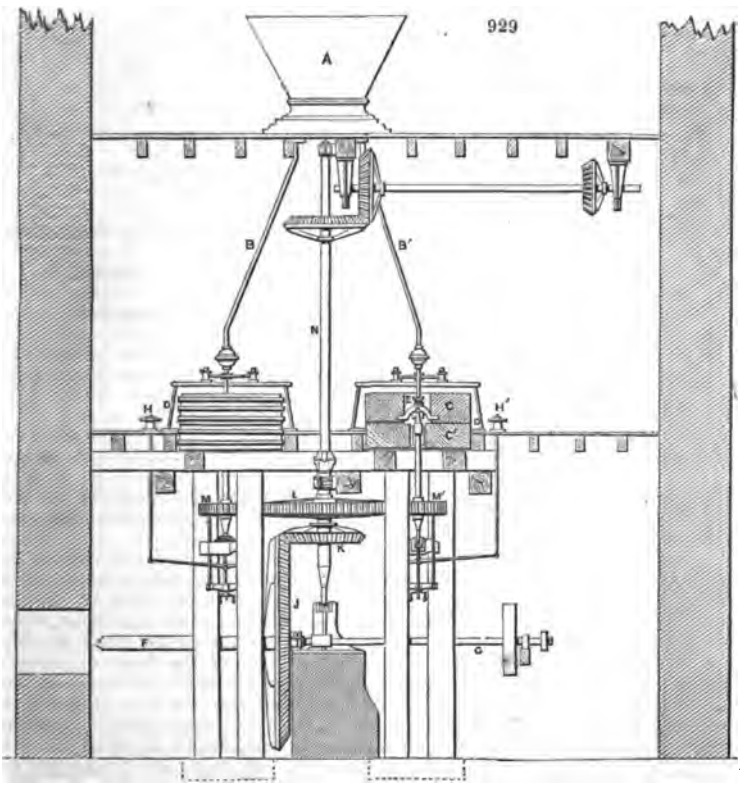
These runners have no progressive motion but have free play to rise or fall on axis c, and in the stay slots g g.

The following dimensions and particulars are derived from one of the edge mills recently working at the Fabrica La Constante in the province of Guadalajara, Spain.

Diameter of edge runner	6 feet.
Width of do. do.	Centre 20 in. edge 16 in.
Weight of do. do.	3 tons 15 cwt.
Speed of runner	200 feet per minute.
Diameter of interior circle of runner	4 feet.
Gauge of stuff previous to its being ground	10 holes to the lineal inch.
Do. after it leaves the mill	60 " "
Quantity of stuff reduced per 10 hours	350 lbs.
Horse power employed	7.

In some machines erected at the Real-del-Monte mines in Mexico the stones were 6 feet in diameter and 12 inches wide. They were fitted with a ring of wrought iron 3 inches thick. Each pair of runners revolved round a centre on its own axis, in a cast iron basin of which the bottom was 7 inches thick. At first good results were obtained, each mill if kept constantly at work ground nearly ten tons per week; but as their axles, and particularly the wrought iron rings and cast iron bottoms, began to wear hollow and to lose an even surface, the grinding rapidly diminished, and with one year's work they were completely worn out.

The chief advantage of this machine is its simplicity of construction and consequent small first cost; but all its parts require to be made of great strength, and therefore of proportionate weight; hence, in addition to the rapid wear to which it is liable, this apparatus becomes objectionable for countries where transit of heavy machinery is more than ordinarily difficult and expensive.



Horizontal mill.—For the purpose of reducing auriferous and argentiferous ores to an exceedingly fine powder, and where dry grinding is essential, no apparatus has

been found more effectual than the horizontal mill. It affords the largest area of frictional surface for the least wear and tear, and accomplishes equal results at a cost not exceeding one-fourth of that incident to the edge mill.

The construction of the horizontal mill will be rendered intelligible by the aid of the preceding illustration, *fig.* 929, in which one pair of stones is shown in section. A is a circular hopper, into which the stuff to be ground is introduced; B B, small pipes of sheet iron, for delivering the stuff between the surfaces of the runner C and bed-stone C'; D, casing enclosing the runner into which the ground material is delivered; E, hole in centre of runner; F, driving-shaft, with continuation shaft G, for giving motion to a Jacob's ladder if requisite; H H', regulating screw for elevating runner C; J, driving-wheel; K, crown-wheel; L, wheel giving motion to pinions M M'; and N, vertical shaft, to drive any supplementary apparatus which may be requiring such, as sizing sieve, &c. Four pairs of stones are usually driven by the wheel L. The surface of the runner is in contact with the bed-stone, from the periphery to within one-third of its diameter. The line of the runner then feathers upwards, in order to receive the stuff freely and to equalise the resistance throughout the area of the bed-stone.

The following particulars will convey much practical information relative to this machine: —

Diameter of stones	4 feet 2 inches.
Thickness of bed-stone	12 inches.
Ditto runner	14 inches.
No. of revolutions of stone per minute	108.
Gauge of stuff in stopper	100 holes to the square inch.
Ditto on delivery	3600 ditto.
Quantity of stuff ground per 10 hours	1 ton per pair of stones.
Power employed in horses	About 5 per ditto.
Revolutions of sizing sieve	23 per minute.
Diameter of ditto	30 inches.
Length of ditto	108.
No. of holes per square inch in sizing sieve	3600.
Character of runner	Coarse conglomerate.
Ditto bed-stone	Compact quartz, moderately hard.
Duration of runner	Average 18 weeks.
Ditto bed-stone	Ditto 22 ditto.
When dressed	Every third day.

From a series of practical experiments made on the same stuff by these several mills, the following results have been obtained: —

	No. of Holes per sq. in. in Sizing Sieve.	Quantity of Stuff ground in 10 Hours.	Horse Power.	Cost per Ton.
		Cwts.		*s.* *d.*
1. Horizontal mill	3600	20	5	2 3
2. Crushing mill	3600	13	5	1 7
3. Edge mill	3600	13	7	6 10

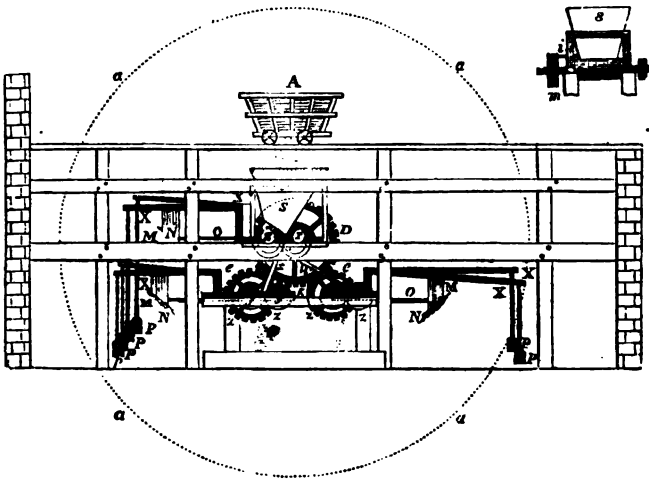
J. D.

The *crushing machines* which are in general use at Alston Moor and the northern mines of this country, and where they have been employed for upwards of fifty years, differ in some respects from those described.

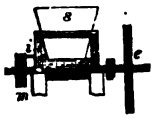
This machine is composed of one pair of fluted cylinders, *x x*, *fig.* 930, and of two pairs of smooth cylinders, z z, z' z', which serve altogether for crushing the ore. The two cylinders of each of the three pairs turn simultaneously in an inverse direction, by means of two toothed wheels, as at *m*, *fig.* 931, upon the shaft of every cylinder, which work by pairs in one another. The motion is given by a single water wheel, of which the circle *a a a* represents the outer circumference. One of the fluted cylinders is placed in the prolongation of the shaft of this wheel, which carries besides a cast iron toothed wheel, geered with the toothed wheels *e e*, fixed upon the ends of two of the smooth cylinders. Above the fluted cylinders there is a hopper, which discharges down between them, by means of a particular mechanism, the ore brought forward by the waggons A. These waggons advance upon a railway, stop above the hopper, and empty their contents into it through a trap-hole, which opens outwardly in the middle of their bottom. Below the hopper there is a small bucket called a shoe, into which the ore is shaken down, and which throws it without ceasing upon the cylinders,

in consequence of the constant jolts given it by a crank-rod, *l* (*fig.* 931), attached to it, and moved by the teeth of the wheel *m*. The shoe is so regulated, that too

930



931



much ore can never fall upon the cylinders and obstruct their movement. A small stream of water is likewise let into the shoe, which spreads over the cylinders, and prevents them from growing hot. The ore, after passing between the fluted rollers, falls upon the inclined planes N N, which turn it over to one or other of the pairs of smooth rolls.

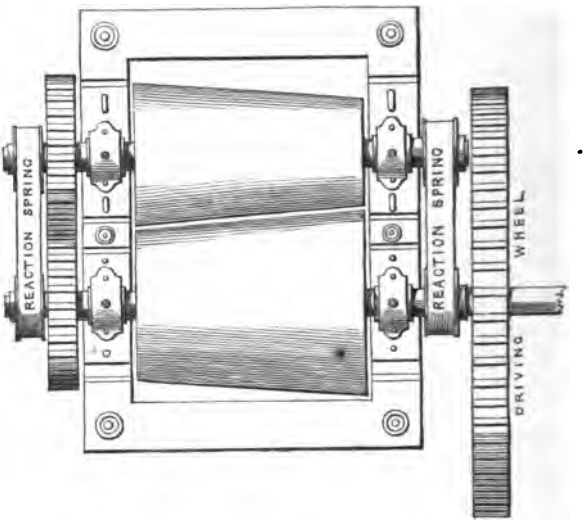
These are the essential parts of this machine; they are made of iron, and the smooth ones are case hardened, or *chilled*, by being cast in iron moulds. The gudgeons of both kinds move in brass bushes fixed upon iron supports *k*, made fast by bolts to the strong wood-work basis of the whole machine. Each of the horizontal bars has an oblong slot, at one of whose ends is solidly fixed one of the plummer-block or bearers of one of the cylinders *f*, and in the rest of the slot the plummer-blocks of the other cylinder *g* slides; a construction which permits the two cylinders to come into contact, or to recede to such a distance from each other as circumstances may require. The movable cylinder is approximated to the fixed ones by means of the iron levers X X, which carry at their ends the weights P, and rest upon wedges M, which may be slidden upon the inclined plane N. These wedges then press the iron bar O, and make it approach the movable cylinder by advancing the plummer-block which supports its axis. When matters are so arranged, should a very large or hard piece present itself to one of the pairs of cylinders, one of the rollers would move away, and let the piece pass without doing injury to the mechanism.

Besides the three pairs of cylinders which constitute essentially each crushing machine, there is sometimes a fourth, which serves to crush the ore when not in large fragments, for example, the *chats* and *cuttings* (the moderately rich and poorer pieces), produced by the first sifting with the brake sieve. The cylinders composing that accessory piece, which, on account of their ordinary use, are called *chats-rollers*, are smooth, and similar to the rollers z z and z′ z′. The one of them is usually placed upon the prolongation of the shaft of the water-wheel, of the side opposite to the principal machine; and the other, which is placed alongside, receives its motion from the first, by means of toothed wheel-work.

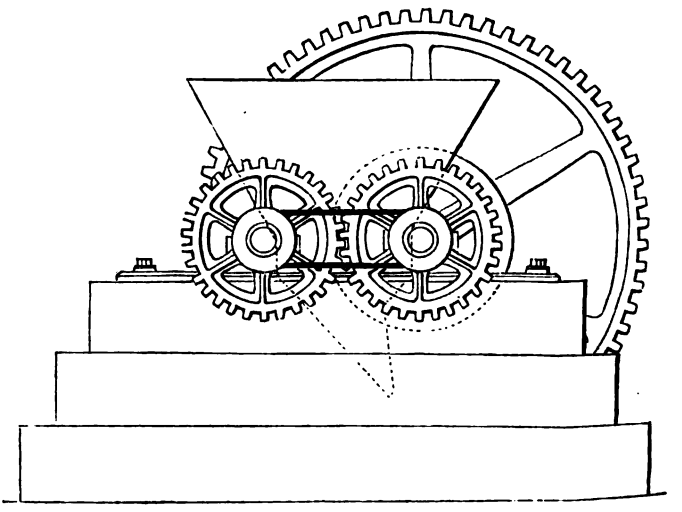
Mackworth's Patent Crushing Rollers, figs. 932 and 933, for Coal and other Minerals. These rollers are made conical to equalise the wear, and as one roller travels faster than the other, the fragments are partially turned over, so as to present their weakest line of fracture to the direction of the crushing force. Less power is required to work these rollers. In lieu of the counterbalance weight usually employed to allow the rollers to separate and pass excessively hard fragments, and to bring the rollers together again, the machine is made more compact and simplified by connecting 2 brass collars, in which the rollers work by a number of bands or cords, of vulcanised indiarubber strongly stretched. A compound cord of indiarubber, 3 inches in diameter, composed of 144 small and separate cords, when stretched

to double its natural length gives a strain of 3 tons. The brass collars do not revolve.

932



933



GRINDSTONE. Grinding-stones or grit-stones, are varieties of sandstone, most of those which are celebrated being obtained from the sandstones and millstone grits of the coal measures. Mr. Knight describes the best known varieties, which are the following:—

NEWCASTLE GRINDSTONES. These abound in the coal districts of Northumberland, Durham, Yorkshire, and Derbyshire. They are selected of different degrees of coarseness and density, according to the work for which they are required.

BILSTON GRINDSTONE is a similar description of stone, of great excellence, of a lighter colour, much finer, and of a very sharp nature, and at the same time not too hard. It is confined to a small spot of limited extent near Bilston in Staffordshire, where it lies above the coal.

WICKERSLEY GRINDSTONES. These are obtained from a village about 9 miles east of Sheffield, and are much used for the finer description of edge tools.

SHEFFIELD GRINDSTONE. A hard coarse grit stone, used for grinding large files and the like; it is obtained from Hardsley, about 14 miles north of Sheffield.

DEVONSHIRE BATTS, are obtained near Collumpton,

YORKSHIRE GRIT and CONGLETON GRIT, are other varieties from which grindstones are manufactured.

BURR STONES. These are very celebrated; they are found at La Ferté-sous-jouarre (Seine et Maine), and are said to be unequalled for grist mills. The combined roughness and hardness of this tertiary quartz deposit give it immense advantages. The stones formed of this rock are usually pieced, which renders them very expensive.

GRIT. A peculiar hard sandstone. See MILLSTONE GRIT.

GROATS, EMBDEN. — When oats are deprived of their integuments, they are called *groats*, and when these are crushed, they are known as *Embden groats*. Oatmeal is prepared by grinding the grains.

GROVE or GROOVE. A mining term in Derbyshire. "The mine, or work that a man is employed in. Hence it is, if a question be asked, Where is Tom to day?—He is gone to the groove, he is at the groove. Sometimes it is used for the shaft, and miners are commonly called *groovers*."—*Hooson's Miner's Dictionary.*

GROWAN. A local term applied in Cornwall to granite in an imperfect state. either through decomposition, or irregular formation. It is said that the term is sometimes applied to the solid granite. We have never heard it so used, and the miners and the quarrymen draw a well defined line between a granite and a growan.

GUAIACUM. (*Gaiac*, Fr.; *Guajaharz*, Germ.) Both the wood and resin are imported; they are used medicinally. It is known that, after the discovery of the New World, when the first syphilitic diseases showed themselves in Europe, the origin of which was erroneously ascribed to Santo Domingo, the guaiacum wood was considered as specific against this disease. The historian Herrera informs us that one pound of the wood was at that period paid in Spain with seven piastres. The gum which exudes from the wood, and possesses, as it may be conceived, the medicinal qualities in a much higher degree, is now valued at seven pence per pound. The quantity exported from Santo Domingo in 1855 amounted to 11,883 lbs., valued at £371.—*Consul's Report.*

GUANO. This extraordinary excrementitious deposit of certain sea-fowls, which occurs in immense quantities upon some parts of the coasts of Peru, Bolivia, and Africa, has lately become an object of great commercial enterprise, and of intense interest to our agricultural world. More than twenty years ago it was exhibited and talked of merely as a natural curiosity, but since that time the quantity imported into England alone has risen from 30,000 to 300,000 tons (in 1855), the value of which was estimated at no less than £3,000,000, as shown by the following numbers, from the "Statistical Abstract of the United Kingdom, from 1842 to 1856."

Imports of Guano, from 1842 *to* 1856.

Year	Quantity imported in Tons.	Year	Quantity imported in Tons.
1842	20,398	1850	116,925
1843	30,002	1851	243,014
1844	104,251	1852	129,889
1845	283,300	1853	123,166
1846	89,203	1854	235,111
1847	82,392	1855	305,061
1848	71,414	1856	191,501
1849	83,438		

During the last two years the quantity imported has somewhat diminished and hence the rise in price, from £11 to £14 per ton. It is curious that, though situated at so great a distance from the sources of supply, Great Britain is by far the largest consumer of Guano, if we may credit the following.

Statement of the Quantities Exported from the Cincha Islands during the Years 1850–1.

Tons of Guano sent to —	1850.	1851.
England	102,421	150,653
France	1,429	
United States	14,250	38,371
China	252	
Total	118,352	189,024

Natural History and Geography.—Huano in the language of Peru, signifies dung; a word spelt by the Spaniards, guano.

The conditions essential for the preservation of these excrements appear to be the existence of a soil consisting of a mixture of sand and clay, in a country where the birds are allowed to live for ages undisturbed by man or man's works, and where, moreover, the climate is very dry, free not only from rain, but also from heavy dews.

These conditions appear to have been combined to a remarkable extent on the coasts of Peru and Bolivia, between latitudes 13° north, and 21° south of the equator, for although beyond this region the flocks of cormorants, flamingoes, cranes, and other sea-fowl, appear to be equally numerous, yet the excrement is rapidly carried away by the rain or dew.

It is then the dryness of the climate chiefly which has permitted the guano to accumulate on these coasts, for, says Mr. Darwin*—"In Peru real deserts occur over wide tracts of country. It has become a proverb that rain never falls in the lower part of Peru." And again:—"The town of Iquique contains about 1000 inhabitants, and stands on a little plain of sand at the foot of a great wall of rock, 2000 feet in height, the whole utterly desert. A light shower of rain falls only once in very many years." Indeed since three fifths of the constituent parts of guano are soluble in cold water Prof. Johnstone very justly observes that†, "A single day of English rain would dissolve out and carry into the sea a considerable portion of one of the largest accumulations; a single year of English weather would cause many of them entirely to disappear."

Such being the case, we might expect to find similar accumulations in other hot and dry climates, as in Egypt, and in Africa, *e. g.* in the neighbourhood of the Great Desert; and only a few years since a considerable deposit of guano was found in the Kooria Mooria Islands.

In Peru the natives have employed it as a manure from the remotest ages, and have by its means given fertility to the otherwise unproductive sandy soils along their coasts. While Peru was governed by its native Incas, the birds were protected from violence by severe laws. The punishment of death was decreed to the persons who dared to land on the guaniferous islands during the breeding period of these birds, and to all persons who destroyed them at any time. Overseers were appointed by the government to take care of the guano districts, and to assign to each claimant his due share of the precious dung. The celebrated Baron Von Humboldt first brought specimens to Europe in 1804, which he sent for examination to Fourcroy, Vauquelin, and Klaproth, the best analytical chemists of the day; and he spoke of it in the following terms:—"The guano is deposited in layers of 50 or 60 feet thick upon the granite of many of the South-sea islands off the coasts of Peru. During 300 years the coast birds have deposited guano only a few lines in thickness. This shows how great must have been the number of birds, and how many centuries must have passed over in order to form the present guano beds."

There appear to be three varieties in Peru; the white, grey, and red, the first being the most recent, and the last the oldest; and in the midst of the great accumulations of the last kind, bones and feathers of birds are found (*Frezier*), as if to remove any doubt which might still remain as to its origin.

Cincha Island Guano.—Much of the so-called Peruvian guano, is exported from the Cincha islands. They are three in number, and lie in one line from north to south about half a mile apart. Each island is from 5 to 6 miles in circumference, and consists of granite covered with guano in some places to a height of 200 feet, in successive horizontal strata, each strata being frem 3 to 10 inches thick, and varying in colour from light to dark brown. No earthy matter whatever is mixed with this vast mass of excrement. At Mr. Bland's visit to these islands in 1842, he observed a perpendicular surface of upwards of 100 feet of perfectly uniform aspect from top to bottom. In some parts of these islands, however, the deposit does not exceed 3 or 4 feet in thickness. In several places, where the surface of the guano is 100 feet or more above the level of the sea, it is strewed here and there with masses of granite, like those from the Alpine mountains, which are met with on the slopes of the Jura chain. These seem to indicate an ancient formation for the guano, and terraqueous convulsions since that period. No such granite masses are found imbedded within the guano, but only skeletons of birds.

The accompanying wood-cut, *fig.* 934, shows the nature of the formation.

The export of the guano has increased considerably during the last few years: between 300,000 and 400,000 tons are the annual amount at present, which is effected by the aid of 900 working hands, 320 of them being Chinese, who enter into contracts to serve their employer (the Government contractor), Don Domingo Elias, for 4 dollars a month, renewing it, if they choose, with the increase of 4 dollars monthly, and a bonus of 120. Those who work on their own account are paid 8 and 10 rials, 4 and 5 shillings, for each cart that they load. They live in a collection of dirty huts made of bamboo and mud; they, nevertheless, appear to be happy and contented, and in

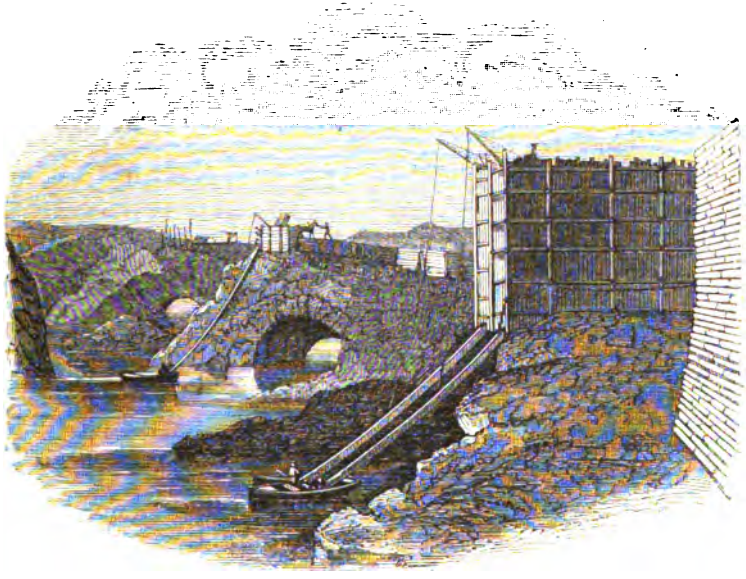
* Researches in Geology and Natural History; p. 428.
† On Guano. Journal of the Agricultural Society of England, vol. ii. p. 315.

general are well conducted. The men with pickaxes work their way into the guano, leaving a sort of wall on either side; here it is so hard that it requires a heavy blow

934

to remove it. It is then conveyed in wheelbarrows either direct to the mouths of the shoots on the edge of the cliffs, or to the huge carts running on tramways for the same purpose. The colour varies very much—in some parts being as dark as warm sepia, and in others as light as that of a Bath brick.

935



The smell of ammonia is said to be very powerful, so much so, in fact, as to affect the eyes of the workmen; crystalline deposits of various ammoniacal salts are also

found amongst the guano. The guano heaps are surrounded by a high fence to prevent its being blown away by the wind, near the mouths of the canvas tubes or shoots, which are sometimes 70 feet long, through which it is conducted to the boats. See *fig.* 935.

As in Peru, the surface of the guano is covered with skeletons of birds, and bones of seals. It is also perforated by numberless holes, running in every direction, like a rabbit warren. These are made by a bird about the size of a pigeon, which remains hidden during the day, sallying forth at dark to fish. Gold and silver ornaments are also discovered occasionally, having been buried by the ancient inhabitants more than three centuries ago.

It is quite unnecessary here to insist on the value of guano as a manure. This is a point established beyond all question by nearly every agriculturist in the kingdom; and recorded by all classes of writers on agricultural subjects; it has been the means moreover of converting the sandy desert around Lima into a soil capable of raising abundant crops of maize; hence the Peruvian proverb, "Huano, though no saint, works many miracles."

Commercial varieties.—The following appear to be the chief: —

1. Peruvian.
2. Augamos.
3. Ichaboe.
4. Patagonian.
5. Saldanha Bay.
6. Kooria Mooria.
7. African.
8. Indian.

Chemistry.—Guano being an article of so great value to the agriculturist as a manure, and being liable not only to adulteration to a very great extent, but also varying when genuine considerably in quality, it is highly important to have some means of ascertaining its value. This cannot be done satisfactorily by ever so experienced a dealer by mere inspection, and therefore, both for the buyer and the seller, resort is necessary, for a knowledge of its compound parts, to the analysis of the chemist.* Such being the case, we must first ascertain the composition of genuine guano, and then inquire upon which of its several constituents its value as a manure depends.

The following is one of the earliest analyses by Fourcroy and Vauquelin, of a sample of guano presented to them by Baron Von Humboldt, showing the composition in 100 parts: —

Urate of ammonia	9·0
Oxalate of ammonia	10·6
Oxalate of lime	7·0
Phosphate of ammonia	6·0
Phosphate of ammonia and magnesia	2·6
Sulphate of potash	5·5
——— soda	3·3
Sal ammoniac	4·2
Phosphate of lime	14·3
Clay and sand	4·7
Water and organic matter	32·2

But perhaps the *constitution* of guano is better exhibited by the following analysis of three sorts by Denham Smith.

AMERICAN GUANO. — *Analysis of three sorts by Denham Smith.*

1. *Constituents soluble in hot Water* (*in* 100 *parts of guano*).

	I.	II.	III.
Phosphate of lime	0·186		0·110
Phosphate of soda	0·120		
Phosphate of ammonia and magnesia	0·564	0·784	0·133
Uric acid	2·516		
Urate of ammonia	15·418		
Organic matter	1·180	0·860	0·756

* Liebig's "Chemistry in its applications to Agriculture and Physiology," p. 272.

2. *Constituents soluble in cold water* (*in* 100 *parts*).

	I.	II.	III.
Water	22·200	20·420	7·700
Sulphate of potash	8·00		
Sulphate of soda	- -	23·944	19·177
Phosphate of potash	- -	7·732	4·947
Phosphate of soda	- -	- -	3·60
Phosphate of ammonia	6·33	6·124	
Phosphate of lime			
Oxalate of ammonia	7·40	9·39	
Oxalate of soda	- -	- -	10·563
Chloride of potassium	- -	- -	4·163
Chloride of sodium	- -	- -	28·631
Chloride of ammonium	2·55	- -	3·030
Organic matter	1·500	0·668	2·553

3. *Constituents insoluble in water* (*in* 100 *parts*).

	I.	II.	III.
Phosphate of lime	19·750	6·270	13·113
Phosphate of magnesia	2·030	0·874	2·580
Oxalate of lime	2·560	10·958	
Sand, &c.	15·60	0·720	0·420
Peroxide of iron and alumina	- -	- -	0·150
Humus	2·636	0·862	0·836
Organic matter	3·456		
Water	- -	4·974	
Loss	0·044	0·498	

We may also quote the following analysis by Dr. Ure, of guano, imported from Bolivia, by the "Mary Anne," being the first cargo thence imported.

It was of a pale yellow-brown colour, dry, partly pulverulent, partly concreted, in small lumps. Its mean specific gravity was 1·63.

The *soluble* portion was found to contain: —

Urea	5·0
Sulphate of potash	7·9
Chloride of sodium	5·0
Phosphate of ammonia	5·5
Oxalate of ammonia	0·6
	24·0

The *insoluble* portion contained: —

Silica	2·25
Phosphate of lime	9·00
Phosphate of magnesia and ammonia	1·25
Urate of ammonia	15 27
Undefined nitrogenised organic matter, yielding by combustion with soda lime 17·05 parts of ammonia	41·73
	69·50

The total quantity of ammonia yielded by it, was 20·95 per cent.

Analysis of Cincha Island Guano. (*Ure.*)

		Ammonia
Matter soluble in water	47·00	
consisting of—		
Sulphate of potash, with a little sulphate of soda	6·00	
Muriate of ammonia	3·00	0·95
Phosphate of ammonia	14·32	4·62
Sesquicarbonate of ammonia	1·00	0·34
Sulphate of ammonia	2·00	0·50
Oxalate of ammonia	3·23	0·89
Water	8·50	
Soluble organic matter and urea	8·95	
	47·00	
Matter insoluble in water	53·00	
consisting of—		
Silica	1·25	
Undefined organic matter	9·52	
Urate of ammonia	14·73	1·23
Oxalate of lime	1·00 ?	
Subphosphate of lime	22·00	
Phosphate of magnesia and ammonia	4·50	0·32
	53 00	9·80

Valuable as these elaborate analyses are in a scientific point of view, they are quite unnecessary for practical purposes in ascertaining the value of any given sample, for on which of these various constituents does the chief efficacy of guano depend ?

Ammonia.— Undoubtedly *one of the most*, if not *the most*, important constituents of guano is the *ammonia*. Authors differ as to the precise manner in which ammonia and its salts act in promoting the growth, and especially in the development of the nitrogenised compounds of plants; but the fact is placed beyond dispute, whether it be that the ammonia contained in the air is decomposed by the leaves, or that the salts of ammonia are absorbed by the spongioles of the roots in solution in water. Now, it is quite possible that, in the mysterious economy of the life of the plant, the ammonia may perform a slightly different function when in different states of combination, either with hydrochloric, sulphuric, nitric, phosphoric, carbonic, uric, humic, or oxalic acids; and although, as a general rule, we should be inclined to yield the palm in point of utility to the more soluble combinations, yet all experience goes to show that the value of an ammoniacal manure may be measured chiefly, if not entirely, by the *quantity* of that compound present, and is in a great measure independent of its state of combination.

Dr. Ure drew a distinction between what he called the *actual* and *potential* ammonia, *i. e.* between ammonia and ammoniacal salts ready formed, and compounds, such as uric acid, which during their decay are gradually converted into ammonia. It appears that recent guano contains from 3 to 5 per cent. of uric acid, whilst the older deposits contain generally less than 1 per cent. No doubt the guano at the time of its deposition consisted chiefly of uric acid; and it is this uric acid which has become converted into salts of ammonia; for the excrements of birds which live chiefly on fish are found to contain from 50 to 80 per cent. of uric acid. It is also an established truth in agricultural chemistry that a manure which contains bodies capable of *gradually* yielding up any valuable compound, such as ammonia, are more useful than those which contain that compound ready formed, and in the state of soluble combinations, which the first storm of rain may wash away from the roots of the plants, where they are required. Nevertheless, admitting the truth of all this, the writer is of opinion (and he believes this is the general experience of agriculturists) that the importance of this distinction between *actual* and *potential* ammonia has been rather exaggerated; and that generally it is enough for all practical purposes, in estimating the value of a guano, to determine the total quantity of nitrogen present in every form, and to consider it as representing an equivalent quantity of ammonia "in esse" or "in posse."

The *amount of ammonia* corresponding to the total quantity of nitrogen in the *several varieties of guano* ranges as follows,—

	Maximum.	Minimum.	Mean.
1. *Peruvian.*			
(From 9 analyses by Way*) of samples imported in 1847-8	18·94	16·40	17·67
From Mr. Way's analyses of 10 samples imported in 1848-9	17·81	15·98	16·189
From Mr. Way's analyses of 14 samples imported in 1849	18·94	16·82	17·88
Mean			17·246
So that the average quantity of ammonia, either existing in, or capable of being yielded by genuine Peruvian guano, may be estimated at about 17 per cent.			
2. *Angamos* guano.			
Ammonia (actual and potential) from two analyses by Dr. Ure	20·89	20·40	20·64
So that this variety is slightly richer in ammonia and nitrogenised compounds than the Peruvian.			
3. *Ichaboe* guano.			
Ammonia (actual and potential) from 11 analyses by Dr. Ure and Mr. Teschemacher	9·5	4·5	7·3
Showing that this variety, as far as regards nitrogenised compounds, is far inferior to the preceding; and the same remark applies to the succeeding varieties, *e. g.*:—			
4. *Patagonian* guano.			
From analyses of 14 samples by Dr. Ure and Mr. Teschemacher	4·68	1·60	2·54
5. *Saldanha Bay* guano.			
From results of analyses of 9 samples by Mr. Way	2·49	0·94	1·68
From results of 9 analyses by Dr. Ure and Mr. Teschemacher	2·10	1·25	1·56
6. *Kooria Mooria.*			
From results of 3 analyses by Mr. Nesbit	0·34	0·17	0·25
From results of 3 analyses by Mr. Apjohn	0·318	0·127	0·22

So that the average quantity of ammonia in the several varieties is—

Peruvian	17 per cent.	Patagonian	2·5 per cent.
Angamos	20 „	Saldanha Bay	1·5 „
Ichaboe	7 „	Kooria Mooria	0·25 „

Potash.—Of the two alkalies, potash and soda, the soil usually contains more than sufficient soda for the supply of vegetation; it is therefore chiefly potash which it is necessary to add in the form of manure.

Besides, even the best guano always contains a considerable quantity of common salt, viz. from 1·0 to 2·5 and even 5 per cent.

Mr. Way, in his valuable paper, "On the Composition and Value of Guano," only gives the quantity of alkaline salts, not having determined the potash; but the average quantity of potash in genuine guano may be seen by referring to the analyses before given in detail, and will be found to vary from 3 to 4 per cent.

However, in estimating the value of guano the knowledge of the quantity of potash is by no means of the same importance as of the ammonia, or the phosphoric acid.

Phosphoric acid.—The phosphoric acid is second in importance to no other constituent than the ammonia; being essential for the development of the seeds and all those parts of the vegetable organism, which serve as foods in the production and restoration of the flesh and bones of animals. It exists in the guano (as is shown by the preceding detailed analyses) in combination with ammonia, potash, soda, and lime.

In most analyses the quantity of phosphate of lime, $3CaO,PO^5$, is given instead of phosphoric acid, PO^5 or $3HO,PO^5$; but 156 parts of phosphate of lime ($3CaO,PO^5$) correspond to 72 of phosphoric acid (PO^5), or as 13 to 6.

* On the composition and money value of the different kinds of Guano. By S. Thomas Way, &c.—"Journal of the Agricultural Society of England," p. 202, &c.

The amount of phosphate of lime in the several varieties of guano is as follows: —

	Maximum.	Minimum.	Mean.
Peruvian.			
From analyses of 9 samples by Way, imported in 1847-8	34·45	19·46	26·95
From Mr. Way's analyses of 10 samples, imported in 1848-9	25·30	21·31	23·30
From Mr. Way's analyses of 14 samples, imported in 1849	28·98	21·28	25·13
Angamos.			
From 2 analyses by Dr. Ure	22·00	18·50	20·25
Ichaboe.			
From 11 analyses by Dr. Ure and Mr. Teschemacher	37·00	26·00	31·50
Patagonian.			
From analyses of 14 samples by Dr. Ure and Mr. Teschemacher	65·5	29·3	47·4
Saldanha Bay.			
From analyses of 9 samples by Mr. Way	60·96	49·01	54·98
From analyses of 9 samples by Dr. Ure and Mr. Teschemacher	62·5	51·0	56·7
Kooria Mooria.			
From analyses of 3 samples by Mr. Nesbit	25·50	2·80	14·15
From analyses of 3 samples by Mr. Apjohn	28·50	5·84	17·17

So that the average quantity of phosphate of lime in the several specimens is as follows: —

Peruvian	25·12	Patagonian	47·4
Angamos	20·25	Saldanha Bay	55·84
Ichaboe	31·50	Kooria Mooria	15·66

These facts are very suggestive as showing how guano, by exposure to air and moisture, has the ammoniacal salts washed out, at the same time, as a consequence, increasing the *ratio* of phosphates.

Organic Matter.—The amount of organic matter in guano, other than ammonia and its salts, is of no great importance in estimating its value as a manure. Not unfrequently the amount of organic matter, containing uric acid or ammoniacal salts, is stated in analyses, as organic matter "*rich in*" or "*containing ammonia*;" but it is obvious such analyses are nearly worthless, the value of the guano depending essentially on the quantity of *nitrogen*, either existing as ammoniacal salts or capable of being converted into them. Good guano contains on an average about 50 per cent. of ash (mineral matters) and 50 per cent. of combustible (organic) matters.

Sand. — The knowledge of the proportion of sand in a guano is of some importance as determining its purity or otherwise. It is easy to understand how a deposit like guano, existing often near the sea-shore, and frequently on a sandy soil, should contain a certain admixture of sand. Some specimens are almost free from it, and few genuine specimens contain more than 1 to 2 per cent.

Common salt. — The presence of common salt in a guano need not surprise us. It is doubtless derived from the sea, partly through the medium of the birds themselves, and partly from the evaporation of the salt spray continually driven upon the coasts by the wind. It is variable in quantity, as we should expect from a knowledge of its origin, ranging in samples of genuine guano from 1 to 5 per cent. Although common salt has been shown * to possess a certain power of absorbing ammonia, yet this is but transient, and the efficacy of guano cannot be said to depend to any extent upon the sea salt present in it. The knowledge of its amount is of great importance, since the guano is not unfrequently adulterated with salt.

Water. — Obviously the larger the amount of water present in guano, the smaller will be the proportion of valuable constituents in a given weight. Genuine guano contains on an average from 10 to about 20 per cent. of water. Many of the salts in guano are likewise deliquescent, so that it has a tendency to become moist by exposure to the air; and this tendency to absorb moisture, is an element of value in the manure, especially in dry seasons.

Calculation of the money value of guano from the results of analyses. — In a most important and interesting paper "On the value of artificial manures,"† Mr. Way

* A. B. Northcote, on the Function of Salt in Agriculture, Phil. Mag. x. 179.
† Agricultural Journal, xvi. 533.

arrives at certain money values for ammonia, phosphoric acid, and the various constituents of guano and other manures, by a comparison with the cost of these several compounds in their ordinary commercial salts. These numbers will be found most valuable to the agriculturist in drawing his own conclusions respecting the value of a guano or other manure from the results of analysis furnished to him by the chemist. They are as follows: —

	£	
Ammonia	56	per ton.
Potash	31	„
Phosphate of lime (insoluble)	7	„
Phosphate of lime (soluble)	32	„
Organic matter	1	„

and the following example of their application may prove useful.

Calculation of the money value of guano, as deduced from the cost of its several constituents in their commercial salts, applied to the mean composition of Peruvian guano deduced by Mr. Way from 78 analyses: —

100 tons contain			£	£
Ammonia	16·5	at	56 per ton	930
Organic matter	52·0	„	1 „	52
Potash	3·5	„	31 „	108
Insoluble phosphate of lime	23·0	„	7 „	161
Soluble phosphate of lime	7·0	„	32 „	224
	Value of 100 tons			£1,475
	Or per ton		£14 15 0	

Hence it is obvious that whilst guano was selling at 11*l* per ton, it was more economical and convenient to employ it than to make an artificial mixture of its chemical constituents; but now that the price has risen to about 14*l*. per ton, it becomes a question whether it will not be possible to produce an artificial compound having equal value as a manure which will compete in price with the guano.

Impurities and adulterations. — In consequence of the high price of guano the great demand for it, and the ease with which the unwary farmer may be imposed upon, guano is adulterated with various substances, and to a great extent. Impositions even have been practised by selling as genuine guano artificial mixtures, made to look so much like guano that the farmer would scarcely detect it. The writer recollects examining a guano which contained 50 per cent. of sand, and no less than 25 per cent. of sea salt; and Dr. Ure gives the following analysis of an article sent to him, which had been offered to the public by advertisement as Peruvian guano which contained —

Common salt	32·0
Sand	28·0
Sulphate of iron	5·2
Phosphate of lime	4·0
Organic matter (from bad guano to give it smell)	23·3
Moisture	7·5
	100·0

In fact so numerous and various are the tricks played with guano, that unless a sample is submitted to a skilful chemist for analysis before purchase, we would strongly recommend the agriculturist to purchase of no one but dealers of unquestionable honour.

Professor Johnstone observes: — "Four vessels recently sailed hence for guano stations, ballasted with gypsum, or plaster of Paris. This substance is intended for admixture with guano, and will enable the parties to deliver from the vessel, a nice looking and light coloured article. The favourite material for adulterating guano at the present moment, is umber, which is brought from Anglesea in large quantities. The rate of admixture is, we are informed, about 15 cwts. of umber to about 5 cwts. of Peruvian guano, from which an excellent looking article, called African guano, is manufactured."

Analysis of Guano.

The following is Dr. Ure's method for the complete analysis of guano: —

1. In every case I determine, first of all, the specific gravity of the guano; which I

take by means of spirits of turpentine, with a peculiar instrument contrived to render the process easy and precise. If it exceeds 1·75 in density, water being 1·0, it must contain sandy impurities, or has an excess of earthy phosphates, and a defect of azotised animal matter.

2. I triturate and digest 200 grains of it with distilled water, filter, dry the insoluble matter, and weigh it.

3. The above solution, diffused in 2000 gr. measures, is examined as to its specific gravity, and then with test paper, to see whether it be acid or alkaline.

4. One half of this solution is distilled along with slaked lime in a matrass connected with a small quintuple globe condenser, containing distilled water, and immersed in a basin of the same. As the condensing apparatus terminates in a water-trap, no part of the ammonia can be lost; and it is all afterwards estimated by a peculiar meter, whose indications make manifest one hundredth part of a grain.

5. The other half of the solution is mixed with some nitric acid, and divided into three equal portions.

a, the first portion, is treated with nitrate of barytes, and the resulting sulphate of barytes is collected, ignited, and weighed.

b, the second portion, is treated with nitrate of silver, and the resulting chloride of silver ignited and weighed.

c, the third portion, has a certain measure of a definite solution of ferric nitrate mixed with it, and then ammonia in excess. From the weight of the precipitated subphosphate of iron after ignition, the known amount of oxide used being deducted, the quantity of phosphoric acid in the soluble portion of the guano becomes known.

d, the three above portions are now mixed, freed by a few drops of dilute sulphuric and hydrochloric acids from any barytes and silver left in them, and then tested by nitrate of lime for oxalate of ammonia. The quantity of oxalate of lime obtained determines that point.

6. The last liquor filtered, being freed from any residuary particles of lime by oxalate of ammonia, is evaporated to dryness and ignited, to obtain the fixed alkaline matter. This being weighed, is then dissolved in a little water, neutralised with acid, and treated with soda-chloride of platinum. From the quantity of potash-chloride of platinum, which precipitates, after being filtered, dried, and weighed, the amount of potash present is deducted; the rest is soda. These bases may be assigned to the sulphuric, hydrochloric, and phosphoric acids, in proportions corresponding to their respective affinities.

7. The proportion of organic matter in the above *solution* of guano, is determined directly by evaporating a certain portion of it to dryness, and igniting. The loss of weight, minus the ammonia and oxalic acid, represents the amount of organic matter.

8. A second portion of a solution of the guano is evaporated to dryness by a gentle steam heat, weighed, inclosed in a stout well-closed phial along with alcohol of 0·825, and heated to 212°. After cooling, the alcoholic solution is decanted or filtered clear, evaporated to dryness by a gentle heat, and weighed. This is urea, which may be tested by its conversion into carbonate of ammonia, when heated in a test tube or small retort. In this way I have obtained from Bolivian guano 5 per cent. of urea; a certain proof of its entire soundness.

9. *Analysis of the insoluble matter.*—One third of it is digested with heat in abundance of borax-water, containing $\frac{1}{100}$ of the salt, filtered, and the filter dried by a steam heat. The loss of weight indicates the amount of uric acid, which is verified by supersaturating the filtrate with acetic or hydrochloric acid, thus precipitating the uric acid, throwing it upon a filter, drying, and weighing it. This weight should nearly agree with the above loss of weight, the small difference being due to soluble organic matter, sometimes called geine and ulmic acid. The uric acid is evidenced, 1, by its specific gravity, which I find to be only 1·25, as also that of the urate of ammonia; 2, by its affording fine purple *murexide* when heated in a capsule along with nitric acid, and then exposed to the vapour of ammonia from a feather held over it; 3, by its dissipation when heated, without emitting an empyreumatic odour.

10. Another third of the solid matter is distilled along with half its weight of slaked lime, and 10 times its weight of water, in the apparatus already described, and the ammonia obtained from it estimated.

11. The remaining third having been ignited, is digested with a gentle heat in weak hydrochloric acid, and the undissolved silica and alumina washed on a filter, dried, and weighed. To the hydrochloric solution, dilute sulphuric acid is added, and the mixture is heated till all the hydrochloric acid be expelled, with the greater part of the water. Alcohol of 0·850 is now poured upon the pasty residuum, and the whole, after being well stirred, is thrown upon a filter. The phosphoric acid passes through, as also the magnesia in union with sulphuric acid. The sulphate of lime, which is quite insoluble in spirits of wine, being washed with them, is dried, ignited, and weighed. From the

weight of sulphate of lime, the quantity of phosphate of that earth that was present becomes known.

12. Ammonia in excess is now added to the filtrate, which throws down the granular phosphate of ammonia and magnesia. After washing and drying this powder at a heat of 150°, its weight denotes the quantity of that compound in the guano.

13. To the filtered liquor (of 12), if a little ammonia be added, and then muriate of magnesia be slowly dropped in, phosphate of ammonia and magnesia will precipitate, from the amount of which the quantity of phosphoric acid may be estimated.

14. The proportion of oxalate of lime is determined by igniting the washed residuum (of 9), and placing it in an apparatus for estimating the quantity of carbonic acid given off in dissolving carbonate of lime. I have rarely obtained more than ½ gr. of carbonic acid from the insoluble residuum of 100 gr. of good guano, and that corresponds to less than 1½ per cent. of oxalate of lime in the guano. Sometimes no effervescence at all is to be perceived in treating the washed residuum with acid after ignition.

15. The carbonate of ammonia in guano is readily determined by filtering the solution of it in cold water, and neutralising the ammonia with a test or alkalimetrical acid.

16. Besides the above series of operations, the following researches must be made to complete our knowledge of guano. The insoluble residuum (of 10), which has been deprived by two successive operations of its uric acid and ammonia, may contain azotised organic matter. It is to be therefore well dried, mixed with 5 times its weight of the usual mixture of hydrate of soda and quicklime, and subjected to gentle ignition in a glass or iron tube closed at one end, and connected at the other with an ammonia-condensing apparatus. The amount of ammonia being estimated by a proper ammonia meter, represents the quantity of azote, allowing 14 of this element for 17 of ammonia, being the potential ammonia corresponding to the undefined animal matter. In a sample of Peruvian guano I obtained 5 per cent. of ammonia from this source.

17. The whole quantitity of ammonia producible from guano is to be determined by gently igniting 25 gr. of it well dried, and mixed with 10 times its weight of the mixture of hydrate of soda and quicklime (2 parts of the latter to 1 of the former). The ammonia disengaged is condensed and measured, as described above.

18. The ready formed ammonia is in all cases determined by distilling a mixture of 100 gr. of it with 50 gr of slaked lime, condensing the disengaged ammonia, and estimating it exactly by the meter.

19. The relation of the combustible and volatile to the incombustible and fixed constituents of guano, is determined by igniting 100 gr. of it in a poised platinum capsule. The loss of weight denotes the amount of combustible and volatile matter, including the moisture, which is known from previous experiments.

20. The insoluble matter is digested in hot water, thrown upon a filter, dried, and weighed. The loss of weight is due to the fixed alkaline salts, which, after concentrating their solutions, are investigated by appropriate tests: 1, nitrate of baryta for the sulphates; 2, nitrate of silver for the chlorides and sulphates; and 3, soda-lime for platinum, for distinguishing the potash from the soda salts.

21. The insoluble matter (of 20) is digested with heat in dilute nitric or hydrochloric acid, and the whole thrown upon a filter. The silica which remains on the filter is washed, ignited, and weighed. The lime, magnesia, and phosphoric acid may be determined as already pointed out.

If, however, the remarks made in an earlier part of this article be correct, it is altogether unnecessary, in order to ascertain the commercial value of a sample of guano, to perform so elaborate a series of operations as that described above.

The following points are all that are required to be investigated: —

The amount of water; organic matter; nitrogen; proportion of ash; analysis of the ash as to phosphoric acid and alkalies — potash and common salt; sand.

1. *Water.*—The most delicate and troublesome operation, is perhaps the determination of the amount of water. If the substance be dried in the water-oven, as is the usual practice, at 212° F., a very large quantity of ammonia is expelled: so that it becomes necessary to desiccate by protracted exposure under a bell glass, over a vessel of sulphuric acid. Even in this manner, the error is not entirely eliminated, and Mr. Way suggests treating the specimen in a shallow platinum dish, with a few drops of hydrochloric acid, which is allowed to soak through the whole: he states, that it may then be dried at 212° F., without loss.

2. *Organic matter.* The proportion of organic matter is determined in the usual way, by burning it off in an open platinum crucible, until nothing is left but the white or brownish white ash, which is then weighed.

3. *Determination of nitrogen.*—This is best performed by Will and Varrentrapp's process, which will be found described under the head of NITROGEN.

4. *Phosphoric acid.*—The phosphoric acid in the ash of the guano is determined by conversion into perphosphate of iron, and then separation as ammonio-magnesia

phosphate, in the same way as has been described under the head of ASHES OF PLANTS. In fact, under this head will be found the general method for the complete analyses of the ashes of organic bodies, which, if it be thought desirable, may be carried out, *in extenso*, in the case of the ash of guano.

5. *Alkalies.*—This is, however, scarcely necessary, so long as the alkalies are determined to ascertain the amount of the valuable alkali potash, and the extent of contamination with common salt.

6. *Sand.*—The quantity of sand is determined by treating a portion of the dried guano with hydrochloric acid and water, till nothing more is dissolved, then igniting and weighing the residue.

Statistics of the guano trade of Peru.—We extract the following from an article lately published in the official journal at Lima:—The exportation of guano began in 1841, under the contract with the house of Messrs. Quiros, Allier, and Co. Up to the end of 1856, the exportation from the Cincha Islands has been 1,967,079 tons, of which 1,626,405 tons were sold, and 23,885 were lost at sea. The stock in hand of the company was 316,789 tons. The gross proceeds of all these sales came to $100,263,518; the charges amounted to $61,008,881, leaving net proceeds, $39,254,647; say at £1 per $5—£7,850,927. In the year 1857 the exportation amounted to 472,965 tons, which, added to 316,789 tons, left on hand in the previous year, gives 789,754 tons; of these 304,589 tons were sold, and 19,156 were lost at sea, leaving 466,009 tons. The net profit this year was $12,538,016, or at $5 per £1—£2,507,603. In the first six months of the present year the exportation has been 169,580 tons, which, added to those in the hands of the consignees at the closing of 1857, or 466,009 tons, gives 635,589 tons. One of the most grievous losses that the government has had to suffer in their exportation of guano has resulted from losses occasioned in the loading of the vessels. The government estimates at 16 per cent. of the guano exported the losses in putting on board, or by guano thrown overboard. To avoid this serious loss, which amounts to several hundreds of dollars, the government has now erected a wharf, where vessels of any tonnage come alongside to load, and by a railway the guano is brought on board the ships from the deposits. Besides this, in order that the captains of vessels should not go to sea with their cargoes of guano in an unseaworthy state, all vessels after receiving their cargoes, come now to Callao to undergo a proper survey. Thus the sea risks are likely to be greatly lessened. By a decree of the 5th of October, 1856, the house of Messrs. Anthony Gibbs and Son, of London, was requested to take charge of the guano sales in Spain, hitherto confided to Messrs. C. De Murrick and Co., of the same city, on a commission of five and a half per cent.; but the former house have given proof of the interest they take in the welfare of Peru, and of all those depending on the revenues of that country, by only accepting and charging four and a half per cent., affording by this item only to the republic a considerable increase in the proceeds of the sale of the guano in Spain, the government has issued a decree of thanks in favour of Messrs. A. Gibbs and Son for their liberality, and besides for the steps they have taken to effect a considerable saving in the warehouse rent and other charges on the guano introduced into Spain. The change of agents in the United States has also caused considerable saving in the commission and charges. The President promises to lay before the Congress the result of the investigation of the inspectors sent to Europe and the United States, which will prove highly interesting.

The stock of guano up to the end of 1857 appears to have been 635,589 tons, at £12 per ton, representing a capital of £7,627,000. This must involve a large amount of interest, to which add warehouse rent, and it will be found that there is great expense involved in keeping it, to say nothing of the deterioration of the quality.

Guano *imported*, 1857:—

	Tons.		Computed real value.
France	1,538		£17,023
Western Coast of Africa (not designated)	2,874		17,234
United States	2,067		8,268
Mexico	2,366		11,830
Brazil	914		4,570
Uruguay	307		1,842
Chili	6,005		78,065
Peru	264,230		3,434,990
Patagonia	1,312		5,248
British possessions in South Africa	4,475		22,375
British West India Islands	1,912		9,560
Other parts	362		2,069
	288,362		£3,613,074

GUANINE. $C^{10}H^5N^5O^2$. An organic base found by Unger in guano. Guano contains about 6 per cent.

GUAVA. This fruit is a native of the two Indies and the Brazils. There are two well known varieties, the *Psidium pomiferum*, or apple-fruited guava; and the *P. pyriferum*, the pear-fruited variety. The pulpy fruits of these trees make with sugar excellent preserves. Imported as Guava jelly.

GUINEA PEPPER. Another name for the Grains of Paradise.

GUM (*Gomme*, Fr.; *Gummi*, *Pflanzenschleim*, Germ.) is the name of a proximate vegetable product, which forms with water a slimy solution, but is insoluble in alcohol, ether, and oils; it is converted by strong sulphuric acid into oxalic and mucic acids.

There are six varieties of gum: 1, gum arabic; 2, gum senegal; 3, gum of the cherry and other stone fruit trees; 4, gum tragacanth; 5, gum of Bassora; 6, the gum of seeds and roots. The first five spontaneously flow from the branches and trunks of their trees, and sometimes from the fruits in the form of a mucilage which dries and hardens in the air. The sixth kind is extracted by boiling water. In commerce, under the name of gum, very different substances are confounded; thus we have *gum elemi* and *gum copal*, which are true resins; and *gum ammoniacum*, which is a gum resin; and *gum elastic* (caoutchouc), which is a peculiar body, differing from either.

Gum arabic and gum senegal consist almost wholly of the purest gum called *arabine* by the French chemists; our native fruit trees contain some *cerasine*, along with arabine; the gum of Bassora and gum tragacanth consist of arabine and bassorine.

Gum arabic, flows from the *Acacia arabica*, and the *Acacia vera*, which grow upon the banks of the Nile and in Arabia. It occurs in commerce in the form of small pieces, rounded upon one side and hollow upon the other. It is transparent, without smell, brittle, easy to pulverise, sometimes colourless, sometimes with a yellow or brownish tint. It may be bleached by exposure to the air and the sunbeams, at the temperature of boiling water. Its specific gravity is 1·355. Moistened gum arabic reddens litmus paper, owing to the presence of a little supermalate of lime, which may be removed by boiling alcohol; it shows also traces of the chlorides of potassium and calcium, and the acetate of potash. 100 parts of good gum contain 70·40 of arabine, 17·60 of water, with a few per cents. of saline and earthy matters. Gum arabic is used in medicine, as also to give lustre to crapes and other silk stuffs.

Gum senegal, is collected by the negroes during the month of November, from the *Acacia senegal*, a tree 18 or 20 feet high. It comes to us in pieces about the size of a partridge's egg, but sometimes larger, with a hollow centre. Its specific gravity is 1·436. It consists of 81·10 arabine; 16·10 water; and from 2 to 3 of saline matters. The chemical properties and uses of this gum are the same as those of gum arabic. It is much employed in calico-printing.

Cherry-tree gum, consists of 52·10 arabine; 34·90 cerasine; 12 water; and 1 saline matter.

Gum tragacanth, is gathered about the end of June, from the *Astragalus tragacantha* of Crete and the surrounding islands. It has the appearance of twisted ribands; is white or reddish; nearly opaque, and a little ductile. It is difficult to pulverise without heating the mortar. Its specific gravity is 1·384. When plunged in water, it dissolves in part, swells considerably, and forms a very thick mucilage. 100 parts of it consist of 53·30 arabine; 33·30 bassorine and starch; 11·0 water; and from 2 to 3 parts of saline matters. It is employed in calico printing, and by shoemakers.

Gum of Bassora; see BASSORINE.

Gum of seeds, as linseed, consists of 52·70 arabine; 28·9 of an insoluble matter; 10·3 water; and 7·11 saline matter. Neither bassorine nor cerasine seems to be present in seeds and roots. For *British Gum*, see DEXTRINE.

GUM ELASTIC. See CAOUTCHOUC.

GUM LAC. See LAC.

GUM RESINS. (*Gomme-résines*, Fr.; *Schleimharze*, Germ.) When incisions are made in the stems, branches, and roots of certain plants, a milky juice exudes, which gradually hardens in the air; and appears to be formed of resin and essential oil, held suspended in water charged with gum, and sometimes with other vegetable matters, such as caoutchouc, bassorine, starch, wax, and several saline matters. The said concrete juice is called a gum-resin; an improper name, as it gives a false idea of the nature of the substance. They are all solid; heavier than water; in general opaque and brittle; may have an acrid taste, and a strong smell; their colour is very variable. They are partially soluble in water, and also in alcohol; and the solution in the former liquid seldom becomes transparent. Almost all the gum resins are medi-

cinal substances, and little employed in the arts and manufactures. The following is a list of them:—assafœtida; gum ammoniac; bdellium; euphorbium; galbanum; gamboge; myrrh; olibanum or frankincense; opoponax; and scammony. Such of these as are employed in the arts or manufactures are described in this work under their peculiar names.

GUM-WOOD. *Eucalpytus piperita*, or blue gum tree of New South Wales. The wood is sent over in large logs and planks; the colour of dark Spanish mahogany, with a blue and sometimes a greyish cast.

GUN BARRELS. See FIRE ARMS.

GUN COTTON. (Syn. *Pyroxiline*; *Fulmicoton*, Fr.) In 1833 M. Braconnot discovered that starch, by the action of monohydrated nitric acid, became converted into a peculiar substance which dissolved in excess of the acid, and was reprecipitated in a granular state on the addition of water. This substance, known as xyloidine, when washed and dried, was found to explode on contact of a light, and even if heated to 356°. It also exploded if subjected to a smart blow. The subsequent researches of M. Pelouze indicated this singular body to be starch, $C^{12}H^{10}O^{10}$, in which one equivalent of hydrogen is replaced by peroxide of nitrogen, or hyponitric acid. The formula of xyloidine would consequently be $\left.\begin{matrix} C^{12}H^{9} \\ NO^{4} \end{matrix}\right\} O^{10}$. On the supposition of this being the correct formula, 100 parts of starch should yield 127·7 of xyloidine, and M. Pelouze obtained from 128 to 150. About thirteen years subsequently to the discovery of xyloidine, M. Schönbein announced his discovery of gun cotton. Chemists immediately saw the analogy between the two substances, for while xyloidine appears to be derived from starch by the substitution of one equivalent of hyponitric acid for one of hydrogen, gun cotton is derived from cellulose ($C^{12}H^{10}O^{10}$, isomeric with starch) by the substitution of two or three equivalents of hyponitric acid for the same number of equivalents of hydrogen.

Preparation. — Gun cotton can be prepared in several ways. The most simple consists in immersing, for a few seconds, well carded cotton in a mixture of equal parts by volume of oil of vitriol of the specific gravity 1·845, and nitric acid of the specific gravity 1·500. The cotton when well saturated is to be removed, and, after being squeezed to repel as much as possible of the excess of adhering acid, well washed in clean cold water. As soon as the water no longer reddens litmus paper, the washing may be considered sufficient. The gun cotton thus prepared is cautiously dried at a heat not exceeding 212°. It is safer to dry at about 150°. The cotton prepared by this means explodes well, but does not always dissolve easily in ether. If, consequently, it is desired to prepare a very soluble cotton for photographic collodion, the following process may be employed, in which, instead of nitric acid, dry nitre is used.

4½ ounces pure dry nitre in fine powder.
30 drams (fluid measure) sulphuric acid, sp. gr. 1·845.
120 grains of well carded cotton.

The cotton is to be well pulled out and immersed in the mixture of the nitre and sulphuric acid. The contact with the acid, &c., is to be insured by stirring and pulling out the cotton with two glass rods. As soon as perfect saturation is effected, which, with good management, will be in about one minute, the cotton is to be thrown into a large pan of water and well rinsed. The vessel is to be continued under a tap until litmus paper is no longer reddened. The cotton is to be squeezed in the folds of a clean towel and exposed (after being again well pulled out) to a gentle heat to dry. It is curious that the most soluble cotton is often the least explosive, although there is reason to believe that the most soluble cotton is that which nearest approaches in constitution to tri-nitro cellulose.

M. Schönbein recommends a mixture of one measure of nitric acid with three measures of sulphuric acid as the best bath for the cotton. The liquid is to be allowed to cool previous to its immersion. He also saturates the cotton with nitrate of potash, by immersing it in a solution of that salt before drying. Cotton prepared in this manner is not adapted for photographic purposes, but it is highly explosive, and therefore well fitted for blasting rocks.

The true constitution of gun cotton is by no means well established. It appears to be very liable to differ in composition according to the method of preparation. According to M. Béchamp it is essential, in order to obtain a cotton both fulminating and soluble in ether, to operate upon the mixture of nitre and sulphuric acid before the temperature (which rises on the ingredients being mingled) has fallen. If cooling has taken place previous to the immersion of the cotton, the resulting pyroxiline is fulminating, but insoluble in ether.

The analyses of MM. Domonte and Ménard, and also of M. Béchamp, agree best with bi-nitro cellulose, while those of Gladstone, Vankerchoff, and Reuter, Schmidt and

Hecker and Pelouze are more in accordance with a tri-nitro cellulose. To add to the difficulty of forming a conclusion on the subject, M. Peligot's analyses agree best with the expression $\left.\begin{matrix}C^{12}H^{10}\\(NO^4)^2\end{matrix}\right\}O^{12}$ which is that of bi-nitro glucose.

According to M. Béchamp xyloidine and pyroxiline are acted on by protacetate of iron, the original substance being regenerated. Thus xyloidine affords starch, and pyroxiline cotton. The regenerated cotton was analysed with the following result:—

	Experiment.	Calculation.	
Carbon - -	43·35	$C^{12}=72$	44·44
Hydrogen -	6·31	H^{10} 10	6·17
Oxygen - -	50·34	O^{10} 80	49·39
	100·00	162	100·00

Béchamp (and others) regard gun cotton as containing nitric acid. The former supports his views with numerous experiments, but there are several disturbing influences preventing the products of the decomposition of gun cotton by alkalies, &c. being regarded as sufficiently known to enable us to express a decided opinion as to its true constitution. It may be mentioned in evidence of this that during the action of caustic potash upon gun cotton, M. Béchamp observed sugar to be produced. The latter chemist in common with many others doubles the formula which we, following M. Gerhardt, have provisionally adopted for cellulose; he moreover formulates the latter substance and its nitro-derivatives thus:—

$C^{24}H^{17}O^{17},5NO^5,2HO$ = pentanitric cellulose.
$C^{24}H^{16}O^{16},4NO^5,\ HO$ = tetranitric cellulose.
$C^{24}H^{17}O^{17},3NO^5$ = trinitric cellulose.
$C^{24}H^{20}O^{20}$ = cellulose.

Explosive substances analogous to gun cotton may be prepared from many organic bodies of the cellulose kind, by immersing them in the same bath as for gun cotton. Among these may be mentioned paper, tow, sawdust, and calico.

When collodion is wanted for an application to cut surfaces, and the cotton is with difficulty soluble in alcoholic ether, a solution may easily be obtained if the cotton be first moistened with acetic ether and the alcoholic ether be afterwards added.

Several of the nitro-derivatives of starch and cellulose undergo spontaneous decomposition when kept for some time in stoppered bottles (*Gladstone*).—C. G. W.

GUNNERY. Under the heads of Artillery and Firearms, we have included nearly every point with which it appears necessary to deal in a work of this description. It is convenient, however, to say a few words in this place of Sir William Armstrong's gun. Instead of being cast like ordinary cannon—or formed of several longitudinal pieces like the Whitworth cannon—or of a hooped or wire-bound tube, as proposed by Captain Blakely, Mr. Mallet, and others; the new gun is formed of an internal steel tube, bound over with strips of rolled iron, laid on spirally, somewhat after the fashion of small-arm barrels, the alternate strips being laid in opposite directions, so that the joints may cross each other, or, in other words, so as to "break joint." This system of construction is, of course, expensive, but it gives great strength with a very small quantity of metal. The internal steel tube is rifled in a very peculiar manner. Instead of having two, three, or four grooves, like ordinary rifled guns—or being formed with an oval bore like that employed by Mr. Lancaster, or with a polygonal bore, as in the Whitworth system—it has a very large number of small grooves close to each other, no less than 40, we believe, in a gun of 2½ inches' bore. The shot or shell Mr. Armstrong usually makes of cast-iron, of about three diameters in length, and covers it entirely over with thin lead, so that it may readily conform itself to the rifled interior of the bore when forced forward by the explosion of the charge. Provision for loading the gun at the breech is made by cutting a slot near the breech end down from the upper side into the bore, of a sufficient length to admit the elongated projectile and the charge of powder, and of a breadth slightly greater than the diameter of the bore. The bore itself is also slightly enlarged where it opens into the space formed by cutting out the slot, in order that the projectile and powder, after being lowered into the slot, may be easily pressed forward by hand or other means into the bore. In order to close the space formed by the slot after the gun is charged, a movable breech-piece is formed to fit into it, and is furnished with two handles, by means of which it may be lifted out or dropped into its place as required. This breech-piece has fitted to its front face a facet of copper, a portion of which projects slightly, so as to form a disc which, when the breech-piece is forced a little forward, will enter the bore behind the charge, and by its expansion, at the moment of explosion prevent all escape of gas. The slight

forcing forward of the breech-piece is effected by means of a strong screw passing in through the extreme breech end of the gun, and pressing against the rear end of the breech-piece. This screw is turned by a hand lever. The fore end of the breech-piece is bored out at the centre, the bore extending through the copper disc, and into this bore is placed at the time of loading a small discharging cartridge. The "touch-hole," or hole for the detonating plug, is formed in the breech-piece, passing down from its upper side into its bore; so that when the piece is to be discharged the detonating cap or plug is struck, the small discharging cartridge is thereby fired, and its fire is instantaneously communicated to the main cartridge in the bore of the gun itself. With his shells Mr. Armstrong uses a percussion fuse of his invention for causing the shell to burst on striking an object, in case the striking takes place before the time-fuse has operated. In a cylindrical case within the shell Mr. Armstrong fixes a weight or striker, by means of a pin passing through it and the sides of the case. This pin is cut or broken by the shock which the projectile receives in the gun at the instance of firing, and the striker being thus liberated recedes to the rear end of the case, and there remains until the velocity of the shell is checked by coming into contact with some object. When this takes place, the striker, not participating in the retardation of the shell, advances in the case, and causes a patch of detonating composition to be carried suddenly against a fixed point, which fires the composition and ignites the bursting charge in the shell.

Experiments have shown that a 32-pounder gun, constructed upon Mr. Armstrong's system, has a greater range and fires with greater accuracy than any gun at present in use in the navy; and yet, while the former weighs but 26 cwt., the present weighs no less than 95 cwt. We may therefore at once reduce the weight of our naval guns by nearly three-fourths, without impairing their range or aim. This would enormously increase the facility of handling them, and therefore leave us free to greatly reduce the number of men employed to work them. Again, with the breech-loading arm it would probably be found possible to get rid of the running out and in of the gun while in action, by counteracting the recoil in some suitable way; and for this reason, also the number of men required to work them might be very much below the present staff. Again, both the bore and the thickness of the metal of the gun being greatly reduced, the external diameter of the gun will be so small that very small ports only would be necessary, and this would add materially to the safety of the gunners, especially in close action. Another advantage might be gained in the use of certain guns, particularly the bow-chase guns, on board ship. It is always a matter of great difficulty to give such a form to the ship that the muzzles of these may, when the guns are run out, project sufficiently far to carry the fire of the explosion clear of the vessel. With the long, slight Armstrong gun this difficulty would not be experienced. See SHELLS.

GUNNY CLOTH or BAGS. The coarse sacking made in India, which is used for wrapping rice, spices, &c. The Bengal gunny cloth is made of the fibre of a species of *Corchorus*, while that of Bombay and Madras is manufactured from different kinds of sunn-fibre, the *Crotolaria juncea.—Simmonds.*

GUNPOWDER. The discovery of gunpowder has been claimed for Roger Bacon and Schwartz. The ground for this appears to be no more than this. In their writings the earliest recorded mention of the discovery is made in any European language. Roger Bacon, unquestionably antecedent to his German rival, was born 1214 and died 1292; and his work, "De Nullitate Magiæ," appears to have been written about 1270, while Kircher's account gives 1354 as the date of the discovery by Schwartz. It appears, however, that an Arabic manuscript exists in the collection of the Escurial which unmistakably describes gunpowder and its properties, the date of which is anterior to 1250.—*Mallet.*

This well known composition is employed for charging the numerous varieties of fire arms. Its use depends upon the fact that, at the moment of ignition, violent deflagration takes place, accompanied by the evolution of a large volume of gas. It is evident that if the explosion occurs in a limited space, a vast pressure accumulates and becomes a propulsive force. The gas produced by the explosion of good gunpowder occupies nearly 900 times the volume of the powder itself; but, owing to the high temperature, the space occupied by the gas at the moment of formation, is probably nearly 2700 times greater than the volume of the powder. One of the most popular errors regarding the projectile force of explosive substances, arises from the extremely vague meaning generally attached to the words strong, powerful, and other equivalent terms. It is this which leads so many to imagine the possibility of attaining marvellously long ranges by means of the various fulminating substances known to chemists. The latter are unfit for use in firearms, owing to a variety of circumstances. One of them is the extreme rapidity of their explosion. The whole mass appears to be converted into gas at once, whereas in gunpowder the ignition proceeds from

particle to particle. The action of fulminates is also too local; if a portion of any of the more violently explosive substances be fired on a piece of metal, the latter will be perforated or depressed exactly at the spot occupied by the substance, and if it be attempted to use it to charge firearms, they will be destroyed, and yet, in all probability the bullet not projected. Moreover, it is impossible to use fulminates successfully for charging shells, because the latter, instead of being blown into pieces of moderate size, capable of inflicting large wounds and throwing down buildings, become converted into fragments so small as to be far less destructive. The escape of the Emperor of the French, from a recent attempt at his assassination, was probably owing to this circumstance.

It has been found that no composition fulfils so many requisites for charging firearms as a mixture, in due proportions, of sulphur, nitre, and charcoal. It is this composition which, in the form of small grains, more or less polished, constitutes gunpowder. The latter should possess several properties which, although sometimes tending in opposite directions, are not entirely incompatible, and may therefore be nearly attained in practice. Some of the principal of these are the following: — 1. The proportions should be so adjusted that the combustion may be complete, and little residue be left after explosion. 2. The powder should be as little hygrometric as possible. 3. It should be sufficiently, but not too explosive. 4. It should be hard and dense enough to bear carriage without breakage of the grains.

Too great a proportion of carbon and sulphur will cause rapid fouling of the gun, and the explosive force will be less than it should be; too small a proportion of sulphur will render the powder too hygrometric. The presence of soda or chloride of potassium in the nitre will lead to the same fault. The powder must be sufficiently stamped, or it will not possess the fourth requisite.

The history of gunpowder may be conveniently studied under the following heads: —

Preparation of the ingredients.
Mixture and granulation.
Modes of estimating projectile force.
Analysis of gunpowder.

Preparation of the Ingredients.

Preparation of the nitre. — The nitre employed for powder is always in a state of almost absolute purity, especially as regards the presence of the chlorides of potassium or sodium. The crude nitre of commerce contains several impurities, among which are found nitrates of soda and lime, chlorides of potassium and sodium, and sulphates of potash and soda. They are all removed by crystallisation. The principal impurity is common salt. The process of purification is founded on the fact that, the latter substance is almost equally soluble in hot or cold water, whereas nitre is far more soluble in hot than in cold water. The following is the French mode of refining saltpetre: — 1200 kilogrammes are gently heated with 600 litres of water in a copper boiler. The solution is constantly stirred and skimmed, and more nitre is added, until the total quantity is 3000 kilogrammes. As soon as the whole is added, and it is presumed that all the nitre is dissolved, the common salt is removed from the bottom of the boiler. The solution is now to be clarified with glue. For this purpose 400 litres of water are added by small portions, and then 1 kilogramme of the glue dissolved in hot water. The scum, which soon rises, is removed, and the fluid is boiled until clear. The whole is then allowed to cool to about 194°, and the solution of nitre is carefully decanted from the layer of common salt into the crystallising vessel. The latter is a large shallow pan with sloping sides. The fluid is constantly stirred as it cools, in order that the crystals formed may be very small, this is done in order to facilitate the washing process, and also because the fine powdery crystals are well adapted for admixture with the other ingredients. When the crystallising solution is cold the nitre is removed to boxes containing false bottoms, pierced with holes. The aperture in the bottom of the box (below the false bottom) being closed, a saturated solution of pure nitre is poured on the crystals to dissolve out the chloride of sodium. Being already saturated, it is evident it cannot dissolve any of the nitre. After remaining two hours in contact with the nitre, the solution is allowed to run off, and when the dropping has almost entirely ceased, the process of washing is repeated, substituting pure water for the solution of nitre. The product is dried at a gentle heat, being constantly stirred to enable it to retain the pulverulent form. The power (above alluded to) possessed by a saturated solution of nitre, of dissolving other salts has been taken advantage of in one of the processes for analysing saltpetre. Some manufacturers fuse the nitre after it has been purified by crystallisation, this process has several disadvantages, among others that of necessitating machinery to reduce it again to a pulverulent state.

Preparation of the sulphur.— Sulphur may be purified for the gunpowder maker by two processes. In the first the crude article is fused in an iron pot, so contrived that the fire does not play directly on the bottom, but only round its sides. The lighter impurities are to be removed by skimming, while the heavier sink to the bottom. The temperature should not be allowed to rise much above 232°, for it then becomes sluggish, and at 320° it is so thick as to prevent the impurities from being removed.

Sulphur may be more readily and economically purified by distillation. The apparatus for the purpose is exceedingly simple in principle; but the process requires care, and is not entirely free from danger. As it is not intended to obtain the sulphur in the state of flowers, the apparatus for condensation is not required to be kept cold; in fact, the still is purposely placed so near to the chamber of condensation, that the sulphur may be received in the fluid state. There are several points which must be attended to in the construction of an apparatus for the distillation of sulphur; they are as follows: — 1. The crude sulphur must be capable of being introduced, and the refined product removed easily, without air being, at the same time, permitted to enter the still or condenser. 2. Free means of egress for the heated air must be provided. 3. The contrivance for the latter purpose must not allow fresh air to return. 4. The process must be continuous. The still and condenser employed in France for the purification of crude sulphur fulfils all these conditions. The still is in the form of a very wide necked tubulated retort, made of cast iron. It is set in brickwork over a furnace, and opens into a square brick chamber surmounted by a dome. The latter has a rather short chimney over it, containing a valve opening upwards to permit escape of the heated air, but not allowing anything to return. Over what may be termed the tubulature of the retort or still, is placed an iron pot with a tube communicating with it. The pot is heated by the same fire that works the still. The crude sulphur is placed in the pot where it melts, and by raising a plug, which closes the tubulature, may be made to enter the still. The pipe forming the tubulature rises a short distance above the bottom of the iron supply pot. This is in order that any heavy mechanical impurities may sink to the bottom, and not enter the still, and unnecessarily clog it. If the pot be always kept full of melted sulphur, and the latter is permitted to enter by raising the plug, it is evident that no air will find it way into either the retort or condenser. It is exceedingly important that this should be the case, because violent explosions are liable to occur if the highly heated vapour of sulphur comes in contact with an oxidising medium, such as atmospheric air, which would convert it into sulphurous acid. The melted sulphur which collects on the floor of the chamber is allowed to flow out when desired, by means of an iron plug attached to a rod of the same metal. The sulphur is not allowed to run out entirely, so as to permit air to enter, for the reason stated above. The loss occurring during the purification is owing partly to oxidation, resulting in the formation of sulphurous acid, and partly to the fixed impurities contained in the crude material. See also the article SULPHUR.

Preparation of the charcoal.— Of the three ingredients of gunpowder, the most important is generally considered to be the charcoal. Unfortunately the woods which are best adapted for the production of pyroligneous acid, are not fitted for the manufacture of gunpowder; the charcoal must, therefore, be prepared specially. The following are the essential properties of good charcoal for powder: — 1. It should be light and porous. 2. It should yield little ashes. 3. It should contain little moisture. The woods yielding good powder charcoals are black alder, poplar, spindle tree, black dogwood, and chestnut. Hemp stalks are said to yield good charcoal for gunpowder. The operation of preparing the charcoal naturally divides itself into three processes. 1. The selection of the wood. 2. Preparation of the wood previous to carbonisation. 3. The carbonisation.

In selecting the wood care is to be taken to avoid the old branches, as the charcoal made from them would yield too much ashes. The bark is to be rejected for the same reason. The wood is to be cut into pieces from 4½ feet to 6 feet long. If the branches used are more than ¾ of an inch in diameter they are to be split. If the wood be too large, great difficulty will be found in uniformly charring it.

There are two methods employed in the charring of wood for gunpowder. In one, the operation is conducted in pits; but the process more commonly resorted to is distillation in cylindrical iron retorts. There are certain advantages in the pit process, but they are more than counterbalanced by the convenience and economy of distillation. The stills used are about 6 feet long, and 2 feet 9 inches in diameter. The ends of the cylinders are closed by iron plates, pierced to admit tubes of the same metal. Some of the latter are for the introduction during the carbonisation of sticks of wood, which are capable of being removed to indicate the stage of the decomposition, while another communicates with the condenser. The more freely the

volatile matters are allowed to escape the better the quality of the resulting charcoal. If care be not taken in this respect, especially as the distillation reaches its close, the tarry matters become decomposed, and a hard coating of carbon is deposited on the charcoal, which greatly lowers its quality. The process of burning in pits is considered to yield a superior coal, owing to the facility with which the gases and vapours fly off.

The degree to which the burning or distillation is carried, materially influences the nature of the resulting powder. If the operation be arrested before the charcoal becomes quite black, so that it may retain a dark-brownish hue, the powder will be more explosive than it would be if it were pushed until the charcoal had attained a deep black colour. When it has been found that no more volatile products are being given off, the fire is damped, and in a few hours the contents of the cylinders are transferred to well closed iron boxes to cool.

Mixture and Granulation.

A very considerable number of methods have been employed at various times, for effecting that thorough incorporation of the ingredients necessary for the production of a good powder. The oldest method consists in stamping the materials in wooden mortars. The pestles are square shafts of wood ending in brass beaters. The mortars are of wood, and so shaped that any of the composition which may be forced upwards by the blows of the stampers, falls back to the bottom. In order to prevent fracture of the mortars, a piece of wood of the toughest kind should be let in on the spot where the pestle falls. The pestles are raised by means of cogs fixed on a shaft, driven by a water wheel or steam engine.

One of the many methods adopted to mix the nitre, sulphur, and charcoal, is by means of drums containing metallic balls; but this arrangement is inferior to that where edge stones are employed. This last is superior to all others, the product being not only very dense and, therefore, capable of enduring, without becoming pulverulent, the motion unavoidable in carrying it about; but it is also thoroughly incorporated. It is, of course, essential that the stones, and the bed on which they work, should not strike fire during work. To secure this, they are sometimes made of calcareous stone, and sometimes of cast iron. Previous to being subjected to the action of the mill, the ingredients must be pulverised and mixed. The pulverisation may conveniently be effected in wooden drums, containing metallic balls. The pulverised materials, after being sifted or bolted, and weighed out in the proper proportions, are to be inserted in a mixing drum, containing on its inside pieces of wood projecting inwards, so that, as it revolves, complete admixture gradually takes place. The product of the last operation is now ready to be laid on the bed of the mill. During the grinding, the cake is kept moist by the addition, at proper intervals, of enough water to make it cohere. As the stones revolve, a scraper causes the material to take such a position that it cannot escape their action. The cake produced by the action of the stones is ready for graining or corning. For this purpose the cake is subjected to powerful pressure, by means of a hydraulic press. The mass is then broken up and transferred to a species of sieve of skin or metal pierced with holes. A wooden flail is placed on the fragments, and the sieves are violently agitated by machinery. By this means the grains and dust produced by the operation fall through the holes in the skin or metal discs, and are afterwards separated by sifting. Sometimes the machinery is so arranged that the graining and separation of the meal powder is effected at one operation. The meal powder is reworked, so as to convert it into grains. The next operation to which the powder is subjected is glazing. Its object is to render it less liable to injury, by absorption of moisture or disintegration during its carriage from place to place. The glazing is effected by causing the grained powder to rotate for some time in a wooden drum or cylinder, containing rods of wood running from end to end. The grains as they rub against each other and against the wooden ribs, have their angles and asperities rubbed off, and at the same time the surface becomes harder and polished. It is finally dried by exposure to a stream of air, heated by means of steam.

A vast number of experiments have been made, at various times, to discover the proportions of nitre, sulphur, and charcoal best adapted for the production of gunpowder. It has been found, as might have been anticipated, that no general rule can be given, no admixture can be made which shall fulfil every requirement. Those powders which contain the largest quantities of charcoal are, it is true, as powerful as others in projectile force; but they have the disadvantage of attracting more humidity from the air. It is very singular that all nations appear to have found, by trial, the proportions most generally useful for ordinary purposes, and it is worthy of remark, that they all approximate to the percentages required by the very simple formula,

$KO,NO^5 + S + 3C$. In fact, the Prussian powder approaches so closely the theoretical numbers, that they fall within the limits of the errors of analysis, thus: —

Prussian powder.		Theoretical proportions.		
Nitre - -	75·0	KO,NO^5	93 or 1 equivalent	74·8
Sulphur -	11·5	S -	16 „ „	11·9
Charcoal -	13·5	O -	18 or 3 equivalents	13·3
	100·0		127	100·0

When a powder constituted as above is fired, the decomposition is probably as follows (represented in symbols): —

$$KO,NO^5 + S + 3C = 3CO^2 + N + KS.$$

That is to say, the explosion of one equivalent of powder results in the formation of three equivalents of carbonic acid, one of nitrogen, and one of sulphide of potassium. It is evident that these theoretical relations are not *absolutely* the true expression of the phenomena, because, in the first place, gunpowder is merely a mechanical mixture, and not a definite chemical compound; and, in the next, the charcoal is represented by the symbol C as if it were pure carbon, whereas, in fact, even the purest and best made charcoals contain variable amounts of hydrogen, ashes, and oxygen. The hydrogen is partly converted into water and partly into hydrosulphuric acid (sulphuretted hydrogen).

The following are the proportions of the ingredients used in various countries.

Table of the Composition of various Gunpowders.

	Nitre.	Sulphur.	Charcoal.
English war powder - - -	75	10	15
„ sporting ditto - - -	77	9	14
French war powder - - -	75	12·5	12·5
„ sporting ditto - - -	76·9	9·6	13·5
„ blasting ditto - - -	62	20	18
„ „ ditto (another kind)	65	20	15
United States war powder - -	75	12·5	12·5
Prussian war powder - - -	75	11·5	13·5
Russian „ „ - - - -	73·8	12·6	13·6
Austrian „ „ - - - -	75	10	15
Spanish „ „ - - - -	76·5	12·7	10·8
Swedish „ „ - - - -	75	16	9
Chinese „ „ - - - -	75·7	14·4	9·9

Blasting powders contain less nitre than others, the combustion is therefore less perfect, and if used for artillery or small arms, not only is the piece very soon rendered foul, but the ball is projected to a much less distance than is required in practice. In France, where a heavy tax is laid on sporting powders, this difference of composition prevents the cheap blasting powder from being used in fowling pieces.

Modes of estimating the Projectile Force of Gunpowder.

The usual mode of determining the propulsive force of powder is by ascertaining the distance to which it can throw a ball of known weight. The instrument used in this country for this purpose consists of an 8-inch mortar charged with 2 ounces of powder, the balls being in each case of the same size and weight. The French use for the purpose an iron mortar, elevated at an angle of 45°. The mortar is 7·5 inches in diameter. The ball is of bronze, and is only 0·067 inches smaller than the bore of the gun; the windage is, consequently, very small. The charge of powder being 3·2 ounces, and the weight of the ball 65 lbs., the latter should be thrown not less than 437·5 yards.

The force of powder may also be estimated by means of an instrument, called a pendulum gun. It consists of a gun barrel hung at the lower end of a pendulum, so arranged that the amount of angular deviation caused by the recoil may be measured; the balls may also be fired into a cup suspended to a similar pendulum. The data obtained serve to enable the rapidity of motion of the ball, at the moment of discharge, to be calculated by means of formulæ contrived for the purpose.

On the Analysis of Gunpowder.

Several methods have been given by various chemists for the analysis of gunpowder: the following, on the whole, appears the most effective:—The percentage of water is, in the first place, to be determined by drying *in vacuo* over sulphuric acid, until no more diminution of weight occurs. The dried powder, or a fresh quantity, is then to be washed on a filter with boiling water, until nothing more is dissolved out. The residue is to be dried below 212° and weighed; the loss is the nitre. If preferred, the solution of the nitre may be evaporated to dryness, and the residue weighed. The mixture of charcoal and sulphur is then to be digested in a stoppered flask, with bisulphide of carbon; this will dissolve out the sulphur and leave the charcoal. The loss of weight of the dry mixture of sulphur and charcoal will enable the percentages of sulphur and charcoal to be calculated. If it be desired to know the quality of the charcoal, a combustion of it may be made with a mixture of chromate of lead and bichromate of potash. Ordinary charcoal contains from 69 to 74 of carbon, 3·9 to 5·5 hydrogen, 0·5 to 3·0 per cent. ashes. It has been attempted to dissolve out the sulphur with sulphite of soda or caustic potash; but these methods involve several sources of error.

Good gunpowder should not lose more than 1 per cent. of moisture on drying. It should not leave alkaline globules, when exploded on a clean metallic plate. The specific gravity of a good powder should not be less than 1·755; it is sometimes as high as 1·840. The denser the powder the better it endures transportation. As the density cannot be taken in water, owing to the solubility of the nitre, turpentine or benzole must be substituted, a correction being made for the difference in density of the fluid medium.—C. G. W.

GUTTA PERCHA. Although the trees yielding this substance abound in the forests of the Indian Archipelago, the first notice taken of it appears to have been by Dr. W. Montgomerie, in a letter to the Bengal Medical Board, in the beginning of 1843, wherein he recommends the substance as likely to prove useful for some surgical purposes, and supposes it to belong to the fig tribe. In April, 1843, the substance was taken to Europe by Dr. D'Almeida, who presented it to the Royal Society of Arts of London, but it did not at first attract much attention, as the Society simply acknowledged the receipt of the gift; whereas, its value becoming known, they awarded a gold medal to Dr. W. Montgomerie.

The gutta percha tree, or gutta tuban, as it ought more properly to be called, according to Mr. Oxley, belongs to the natural family *Sapoteæ*, but differs much from all described genera, having alliance with both *Achras* and *Bassia*, but differing in some essentials from both. It is the *Isonandra gutta* of Hooker, and is described in the London Journal of Botany, 1848, where it is figured, and in Pereira's *Materia Medica*.

The tree is of a large size, from 60 to 70 feet in height, and from 2 to 3 feet in diameter. Its general appearance resembles the genus *Durio*, or well known *Doorian*, so much so as to strike the most superficial observer. The under surface of the leaf, however, is of a more reddish and decided brown than in the durio, and the shape is somewhat different.

Only a short time ago the gutta percha tree was tolerably abundant on the island of Singapore; but already all the large timber has been felled, and few, if any, other than small plants, are now to be found. The range of its growth, however, appears to be considerable, it being found all up the Malayan Peninsula, as far as Penang. The tree is also found in Borneo, and, there is little doubt, is to be found in most of the islands adjacent.

The localities it particularly likes are the alluvial tracts along the foot of hills, where it flourishes luxuriantly, forming, in many spots, the principal portion of the jungle. But, notwithstanding the indigenous character of the tree, its apparent abundance and wide-spread diffusion, the gutta will soon become a very scarce article, if some more provident means be not adopted in its collection than those at present in use by the Malays and Chinese.

Montgomerie says "a magnificent tree of 50, or more probably 100 years' growth, is cut down, the bark stripped off and the milky juice collected and poured into a trough formed by the hollow stem of the plantain leaf; it quickly coagulates on exposure to the air; but from one tree I am told not more than 20lbs. or 30lbs. are procured."

The mode in which the natives obtain the gutta is by cutting down the trees of full growth, and ringing the bark at distances of about 12 to 18 inches apart, and placing a cocoa-nut shell, spathe of a palm, or such like receptacle, under the fallen trunk, to receive the milky sap that immediately exudes upon every fresh incision. This sap is collected in bamboos, taken to their houses, and boiled, in order to drive off

the watery particles and inspissate it to the consistence it finally assumes. Although the process of boiling appears necessary when the gutta is collected in large quantities, if a tree be freshly wounded, a small quantity allowed to exude, and it be collected and moulded in the hand, it will consolidate perfectly in a few minutes, and have all the appearance of the prepared article.

When it is quite pure the colour is of a greyish white; but, as brought to market, it is more ordinarily found of a reddish hue, arising from chips of bark that fall into the sap in the act of making the incisions, and which yield their colour to it. Besides these accidental chips there is a great deal of intentional adulteration by sawdust and other materials. Some specimens brought to market do not contain much less than ½ lb. of impurities: and even in the purest specimens, one pound of the substance yielded, on being cleansed, one ounce of impurities. Fortunately, it is not difficult to detect or clean the gutta of foreign matter, it being only necessary to boil it in water until well softened, roll out the substance into thin sheets, and then pick out all impurities, which is easily done, as the gutta does not adhere to anything, and all foreign matter is merely entangled in its fibres, not incorporated in its substance. The quantity of gutta percha obtained from each tree varies from 5 to 20 catties, so that, taking the average at 10 catties, which is a tolerably liberal one, it will require the destruction of ten trees to produce one picul. How much better would it, therefore, be to adopt the method of tapping the tree, practised by the Burmese in obtaining the caoutchouc from the *Ficus elastica* (viz. to make oblique incisions in the bark, placing bamboos to receive the sap which runs out freely). True, they would not at first get so much from a single tree, but the ultimate gain would be incalculable, particularly as the tree seems to be one of slow growth; by no means so rapid as the *Ficus elastica*.

Properties of the Gutta percha. — This substance when fresh and pure, is of a dirty white colour, and of a greasy feel, with a peculiar leathery smell. It is not affected by boiling alcohol, but dissolves readily in boiling spirits of turpentine, also in naphtha and coal-tar. A good cement for luting bottles and other purposes is formed by boiling together equal parts of gutta and coal-tar and resin. When required for use, it can always be made plastic by putting the pot containing it over the fire for a few minutes. The gutta percha itself is highly inflammable; a strip cut off takes light, and burns with a bright flame, emitting sparks, and dropping a black residuum in the manner of sealing wax, which in its combustion it very much resembles. But the great peculiarity of this substance, and that which makes it so eminently useful for many purposes, is the effect of boiling water upon it. When immersed for a few minutes in water above 150° Fahr. it becomes soft and plastic, so as to be capable of being moulded to any required shape or form, which it retains upon cooling. If a strip of it be cut off and plunged into boiling water, it contracts in size both in length and breadth.

It is this plasticity when plunged into boiling water that has allowed of its being applied to so many useful purposes, and which first induced some Malays to fabricate it into whips, which were brought into Singapore, and led to its further notice. The natives subsequently extended their manufactures to buckets, basins, and jugs, shoes, traces, vessels for cooling wines, and several other domestic uses. Its easy plasticity and power of retaining any shape given to it when cool, at once pointed it out as suitable for the manufacture of bougies; and accordingly Dr. W. Montgomerie, availed himself of this, made several of the above instruments, and recommended the use of it to the Bengal Medical Board. It also answers very well for the tubes of syringes, which are always getting out of order in hot climates, when made of caoutchouc.

Mr. T. Oxley, surgeon, Prince of Wales Island and Malacca, whose remarks are of much value from his acquaintance with the production of which he writes, says:—

"I observed in the *Mechanics' Magazine* for March, 1847, a notice of several patents taken out for the working of this article by Mr. Charles Hancock, in which an elaborate process is described for cleaning the gutta, as also mention of its having a disagreeable acid smell. The gutta, when pure, is certainly slightly acid, that is, it will cause a very slight effervescence when put into a solution of soda, but is unaffected by liquor potassæ. The smell, although peculiar, is neither strong nor unpleasant, so that the article experimented upon must have been exceedingly impure, and possibly derived a large portion of its acidity from the admixture and fermentation of other vegetable substances. Again; it appears to me that, if the gutta be pure, the very elaborate process described as being necessary for cleaning it, is superfluous. The gutta can be obtained here in a perfectly pure state by simply boiling it in hot water until well softened, and then rolling it out into thin sheets, when all foreign matter can be easily removed. I would recommend that the manufacturers at home should offer a higher price for the article if previously strained through

cloth at the time of being collected, when they will receive the gutta in a state that will save them a vast deal more in trouble and expense than the trifling addition necessary to the original prime cost."

In February, 1847, Mr. Charles Hancock obtained a patent for improvements in the manufacture of gutta percha. In the first place, for the construction of a slicing machine, consisting of a circular iron plate, formed with three radial slots, in which knives are fixed in a similar manner to the irons of an ordinary plane or spoke shave; the shaft which carries the plate is caused to rotate by steam or other power. The lumps of gutta percha drop against the knives, by which they are cut into slices, of a degree of thickness corresponding to the projection given to the knives. These slices are then soaked in a vessel of hot water till they become pliable. Instead of a circular revolving cutter, a vertical cutter or chopper may be used; curved knives may be had recourse to for refractory lumps. The softened slices are next subjected to the action of breakers or rollers with serrated blades, which are mounted transversely over the tank. In front of each breaker there is a pair of fluted feeding rollers; and the pieces of gutta percha are passed to the rollers of the first breaker. There is an inclined endless web mounted upon two rollers, the front one of which is immersed in the water, and the other is situated opposite the space between the feeding rollers of the second breaker. There is a second inclined web placed before the third breaker. There is also a mincing cylinder with radial blades working partly in the water. The feeding-rollers, and the carrying-rollers of the endless webs, are made to revolve in a forward direction, while the breakers, the mincing cylinder, and the agitator, are made to revolve in the opposite direction. The breakers and mincing cylinder should revolve at the rate of from 600 to 800 revolutions per minute, but the feeding rollers and endless webs need not move faster than about one-sixth of that rate. Thus, the substance is reduced to fragments and washed in the water, the heavy impurities falling to the bottom of the tanks, and the light purer matter floating. The water should be used cold. When the gutta percha has a fetid smell, it is treated with carbonate of soda or chloride of lime. The same apparatus may be used for purifying caoutchouc.

Mr. Hancock combined sulphur with gutta percha in the following manner: — He found that if a minute portion of sulphur be used along with a sulphide the best result is obtained; the proper proportions being 6 parts of sulphide of antimony, or hydrosulphide of lime, and 1 part of sulphur to 48 parts of gutta percha. When these materials have been mixed, the compound is put into a boiler and heated under pressure to a temperature of from 260° to 300° F. and it is to be left in this state for a period varying from half an hour to two hours, according to the thickness of the materials. He prefers, for effecting the union of the sulphurous constituent, the following method to the masticating machine. 1st. He subjects the purified gutta percha to the combined action of steam and the fumes of orpiment and sulphur mixed in the proportions stated, in a metal chamber, provided with a steam-tight cover secured by screw-bolts. There is also a steam boiler connected therewith, and when the heat in it is raised to about 280° Fahr., a fire is lighted beneath the pot containing the sulphurising materials. But the gutta percha, &c., should be heated with the steam before it is sulphurised. In from half an hour to two hours the sulphurising is finished. Or, the gutta percha may be rubbed strongly over with the sulphurous mixture and then heated, either dry or with the aid of steam, or it may be coated in the form of a paste.

Another of Mr. Hancock's inventions is to expose the gutta percha to the deutoxide of azote, or chloride of zinc, concentrated and boiling hot, and then washing with an alkaline solution or mere water. Gutta percha thus treated by the action of nitrous gas, as it is evolved from nitric acid and copper, iron, or zinc, becomes exceedingly smooth, and of a lustre approaching to metallic; the same effect is produced upon common unsulphurised caoutchouc. Gutta percha is thus also freed from all stickiness; and if sulphurised it acquires under this treatment the downy softness of velvet. Chloride of zinc and nitrous gas remove the smell of vulcanised caoutchouc in a great measure, especially if it be afterwards washed.

Another invention is that of masticating gutta percha in the proportion of 6 parts with 1 of chloride of zinc; which compound may be afterwards sulphurised. A further modification consists in producing a spongy gutta percha for stuffing sofas, &c. 48 parts of it moistened with oil of turpentine, coal naphtha, bisulphide of carbon, or other proper solvent, 6 parts of hydrosulphide of lime, sulphide of antimony, or other analogous sulphide, 10 parts of carbonate of ammonia, carbonate of lime, or other substance that is either volatile or capable of yielding a volatile product, and 1 part of sulphur. Mr. Hancock mixes these materials together in a masticator, and then subjects them to a high degree of heat, observing the same conditions which are stated in the former description, except only that the heat may be pushed with advantage several degrees higher, say from 260° to 300°.

Various articles are manufactured of ordinary gutta percha, such as single and double texture waterproof fabrics, boots, galoshes, belts, bandages, trowsers and other straps, capes, life-preservers, tubes, knapsacks, caps, cups, and other vessels of capacity, hammer cloths, cotton spinning rollers, backs of cards for carding wool, pianoforte hammers, paper holders, springs, trusses, &c. By taking the gutta percha after it has been sulphurised, and brushing it with a solution of resin in boiling oil (linseed?), placing it in a chamber heated to from 75° to 100° Fahr., and afterwards polishing it by the means usually employed by the japanners, it acquires the lustre of japanned wares.

Mr. Hancock has also contrived a machine for cutting gutta percha into strips or riband, threads, or cord of any required shape. It consists of two grooved rollers of iron or steel, mounted in a suitable framework. The grooves of each roller are semicircular, and the projecting divisions between the grooves are made with knife edges, so as to divide readily any sheet or mass of gutta percha presented to them. The under roller is flanged at both ends, and the upper roller is made to fit inside of these flanges, in order to keep the cutting edges from shifting or being damaged. To cut thin sheets of gutta percha with this machine into strips or ribands, the material is passed through it in a cold state, and only the cutting edges are brought into operation. To make round cord or thread by means of it, either a sheet of gutta percha of a thickness equal to the diameter of the holes formed by the grooves, and at a temperature of 200° Fahr. (produced by supplying it from a feeding-chamber heated to that degree) is passed through the machine, and the threads or cords are received in a tank of cold water, from which they are led away to be wound on reels or drums; or the gutta percha is employed in a plastic state, and passed under a gauge before it enters the machine. If it be desired to produce a cord of a semicircular form in the transverse section, a plane roller is substituted for the lower grooved roller; or should cord of a square, triangular, or hexangular, or any other form be required, the two rollers must be shaped to suit.

Gutta Percha Tubes.—A series of interesting experiments have been made at the Birmingham Waterworks, relative to the strength of Gutta Percha Tubing, with a view to its applicability for the conveyance of water. The experiments were made (under the direction of Henry Rose, Esq., engineer), upon tubes ¾ of an inch diameter, and one eighth, of gutta percha. These were attached to the iron main, and subjected for two months to a pressure of 200 feet head of water, without being in the slightest degree deteriorated. In order to ascertain if possible the maximum strength of the tubes, they were connected with the Water Company's hydraulic proving pump, the regular load of which is 250 lbs. on the square inch. At this point the tubes were unaffected, and the pump was worked up to 337 lbs., but to the astonishment of every one the tubes still remained perfect. It was then proposed to work the pump up to 500 lbs., but it was found that the lever of the valve would not bear this weight. The utmost power of the hydraulic pump could not break the tubes.

The gutta percha being somewhat elastic, allowed the tubes to become slightly expanded by the extraordinary pressure which was applied, but on its withdrawal they resumed their former size.

This tubing is such an extraordinary conductor of sound, that its value, not only to deaf persons, but to the public generally, will speedily be appreciated. It has already been fitted up in dwelling houses, in lieu of bells;—as speaking tubes for giving and receiving messages in mines, railway stations, prisons, workhouses, hotels, and all large establishments, it is invaluable.

Properties of common Gutta Percha.—The gutta percha, purified for manufacturing purposes, is of a reddish-brown colour; it readily becomes electrical by friction and is a bad conductor of both electricity and heat. At the ordinary temperature of our climate, say from 32° to 77°, it possesses about as much tenacity as thick leather, with rather less flexibility; it softens and becomes sensibly doughy towards 120°, although still very tough. Its ductility is such, at a temperature of from 110° to 241°, that it is readily extended into thin sheets, or drawn into threads or tubes; its flexibility and ductility diminish as the temperature becomes lower. It does not possess at any temperature the peculiar elastic extensibility which characterises caoutchouc. Exposed for an hour to a temperature of 14°, its flexibility is slightly diminished.

In its various forms, gutta percha possesses a peculiar porosity, as may be shown in the following manner:— A drop of its solution in sulphuret of carbon is to be placed on a glass slip; the spontaneous evaporation soon reduces this solution to a whitish plate; if it be then examined with the microscope, the numerous cavities with which it is pierced may be distinctly perceived. These cavities may be rendered still more visible by means of a drop of water; the liquid gradually insinuates itself, the mass appears more opaque, and by means of the microscope the cavities are seen to be enlarged.

Similar results are obtained by keeping thin transparent laminæ, obtained by the evaporation, by heat, of a solution of gutta percha immersed in water for a considerable time.

The preceding observations lead us to think, that this substance retaining, in consequence of its porosity, a great many minute particles of air, owes to this circumstance its appearance of possessing a less density than that of water, namely 0·979. In fact, on stretching gutta percha under strong pressure, and immediately cutting the strips thus produced into very small pieces under water, the greater part of the fragments fall to the bottom of the vessel—some immediately, others after absorbing a certain quantity of water. The same result is also obtained by keeping very thin leaves of gutta percha, prepared by different methods, immersed for a month in water deprived of air: their pores becoming gradually filled with the liquid, they became heavier than the water, and then ceased to float. Gutta percha is also heavier in proportion to the length of time it has been exposed to the air, particularly in thin leaves.

The porous structure of gutta percha becomes changed into a fibrous texture when it is drawn out so as to double its length: then retaining but little extensibility, it supports, without breaking, the action of a force equal to double that required for its elongation in the first instance.

Common gutta percha resists cold water, damp, and also the various influences which excite fermentation; but it can be softened, and experience a sort of superficial doughy fusion by the action of the solar rays in summer.

It is not attacked by alkaline solutions, even when caustic and concentrated; ammonia, saline solutions, water containing carbonic acid, the various vegetable and mineral acids, do not act upon it; the weaker alcoholic liquors (wines, beer, &c.) do not touch it; and even brandy scarcely dissolves a trace of it. Olive-oil does not appear to attack gutta percha when cold; when hot, it dissolves a small portion of it, which is again precipitated on cooling.

Sulphuric acid with one equiv. of water colours it brown, and disintegrates it with a sensible evolution of sulphurous acid.

Muriatic acid, in its saturated solution in water at a temperature of 68° F., attacks gutta percha slowly, and gives it a more or less deep brown colour, at length rendering it brittle.

Monohydrated nitric acid attacks it rapidly, with effervescence and an abundant evolution of fumes of hyponitrous acid; the substance is decomposed, and coloured of a brownish-orange red: it becomes doughy, and afterwards solidifies by degrees and remains friable.

In the cold, and even by heat, only a part of the gutta percha (0·15 to 0·22) is dissolved by anhydrous alcohol or ether. Benzine and spirits of turpentine dissolve it partially when cold, but nearly completely if aided by heat. Sulphide of carbon and chloroform dissolve gutta percha when cold; the solutions may be filtered beneath a bell-glass to prevent evaporation; the filter retains the foreign matters of a reddish-brown colour, whilst the solution passes perfectly clear, and almost colourless. The filtered liquid, exposed to the air in a saucer, allows the solvent to escape, and deposits the white gutta percha in a plate of greater or less thickness, which shrinks gradually in proportion to the evaporation of the liquid.

Except the colour, which has disappeared, the gutta percha then offers the characters and properties mentioned above as belonging to the commercial substance. Submitted to a gradually raised temperature, it softens and melts, and may be made to boil without acquiring a sensible colour; the transparent fluid gives abundant vapours, which are condensible into a nearly colourless oily liquid. The portions last distilled have a brownish-orange colour, and a thin layer of carbonaceous deposit remains adherent to the sides of the vessel.

Analysis.—We have said above that alcohol and ether can dissolve only a portion of gutta percha; this is because that substance consists, in fact, of three proximate principles, the separation of which has required very delicate observation, although they are very clearly distinguished by several of their properties.

When gutta percha in thin leaves is brought into contact, in a close vessel, with 15 to 20 vols. of cold anhydrous alcohol, and the temperature raised slowly by means of the water-bath to the point of ebullition (172° F.), and kept at this point during several hours, the liquid, if filtered whilst boiling and left in a closed flask, will, at the end of from 12 to 36 hours, begin to deposit on the sides of the vessel and on the surface of the solution white opaline granules, distant from one another, but some of them in groups; their size will gradually increase for some days. These granules, carefully examined under the microscope, will be found to have the form of spherules truncated by the sides of the vessel. Their surface is either smooth, or bristling with very small transparent, elongated, lamellar crystals. Some superficial fissures appear to indicate

that these spherules are formed of a sort of transparent yellow kernel covered with a white pellicle.

Perhaps no other example is known of this singular crystalline structure. In fact, cold anhydrous alcohol dissolves the whole of the yellow spheroidal substance, whilst the superficial pellicle, in the interior of which the alcohol has substituted itself for the solid globule, appears whiter and less transparent.

The alcoholic solution, which has been for some days depositing this complex spheroidal crystallisation, can again take up by heat a portion of the two proximate principles remaining in the substance, allowing a fresh quantity to crystallise on cooling. The extraction is completed by returning the boiling alcohol several times upon the gutta percha until it no longer dissolves anything.

The solid substance which has resisted the action of the solvent, possesses, with some modifications, the principal properties of crude gutta percha; we shall here call it *pure gutta*. As to the two other organic principles, one is a *yellow resin*, which is much more soluble in cold alcohol than the other, the *white crystalline resin*.

By taking advantage of these different degrees of solubility, we are enabled with time and patience to effect the complete purification of these three principles. The separation may also be effected by treating finely-divided gutta percha with cold ether, which dissolves the mixture of the two resins more abundantly than alcohol; they are afterwards separated from one another by the same treatment already described for alcohol.

The tendency of the white resin to form itself into radiated groups is manifested in a rather remarkable circumstance, which it is easy to reproduce. Narrow ribbons cut from a thin leaf of ordinary gutta percha are to be placed in a tube, and immersed in anhydrous alcohol. The tube is then closed, and left for twenty or thirty days, when a few whitish points appear here and there on the ribbons, and afterwards on the sides of the tube. These points, which become gradually larger, are formed of crystalline tufts of the white resin. Thus this proximate principle is separated directly, and in the cold, even when the atmospheric temperature is gradually rising, for instance during the spring or early summer.

The crystalline white resin, when completely purified by washings with alcohol, and then redissolved in anhydrous alcohol, is deposited by slow spontaneous evaporation in the air, in radiated crystals, forming sometimes symmetrical tufts arranged in stars, and then presenting the appearance of a sort of efflorescence.

Distinctive characters and properties of the three proximate principles which constitute common Gutta Percha. — The most abundant of these three principles, forming at least from 75 to 82 per cent. of the whole mass, is the pure gutta, which presents the principal properties of the commercial substance; it is white, transparent at a temperature of 212° F., when all its parts are melted together; opaque or semi-transparent when cold, from its then acquiring a structure which causes the interposition of air, or of a liquid possessing a different refraction from its own. This structure appears still more distinct than in the natural substance containing all three principles.

In thin sheets, and at a temperature of 50° to 68° F., it is supple, tough, extensible but not very elastic. At 112° F., it softens and turns back upon itself, and becomes more and more adhesive and translucent in proportion to the elevation of temperature, undergoing a sort of doughy fusion, which becomes more distinct towards 212° to 230°. Heated beyond this point, it melts, boils, and distils, furnishing a pyrogenous oil and carburetted gases.

Soubeiran believes the composition of perfectly pure gutta percha to be $C^{10}H^{16}$ corresponding to 87·8 carbon, and 12·2 hydrogen. Faraday found caoutchouc to be 87·2 carbon, 12·8 hydrogen; hence their chemical composition is identical.

Pure gutta, like the other two proximate principles, is quickly rendered electrical by friction, and is a bad conducter of heat; it generally floats on water, but sinks to the bottom as soon as its pores are filled with this liquid. It is insoluble in alcohol and ether, almost completely insoluble in benzine at 32° F.; it is soluble at 77°, and becomes more and more so in proportion as the temperature is raised. The saturated solution at 86° forms itself into a semi-transparent mass when cooled below 32°; alcohol precipitates the pure gutta from its solution in benzine.

At 32°, spirits of turpentine dissolves very little gutta, whilst it disintegrates and dissolves it readily when hot.

Chloroform and sulphide of carbon dissolve the gutta percha in the cold.

After the extraction by means of ether of the two resins interposed in the thin leaves of white gutta percha, leaving the last portion of ether with which they were impregnated to evaporate in the open air, these leaves, enclosed in a flask, experienced, after remaining there for two months at a temperature of from 68° to 82° F., an alteration which appeared to depend on their porosity, the action of the air, and

perhaps the ether retained in their pores. However it be, these leaves had then acquired new properties: they were brittle; exhaled a very distinct sharp odour; brought into contact with an excess of anhydrous ether, they were partially dissolved; the soluble portion, obtained by the evaporation of the ether and desiccation at 194° F., was glutinous and translucent; it became opaque and hard by cooling down to 14° F.

Sulphide of carbon, renewed three times in six days, and evaporated each time after two days' contact, left as residue a white flexible leaf. The portion not dissolved, swelled and transparent, did not appear to undergo any change when left in sulphide of carbon for ten days.

This kind of spontaneous transformation would perhaps become complete if more prolonged; its study will require much time; it will perhaps put us in the way of ascertaining the causes of certain changes observed in some small objects formed of gutta percha. It has already been ascertained, that thin leaves, exposed for eight consecutive days to the action of the sun in moist air, were discoloured, and that their substance had become in great part soluble in ether.

Monohydrated sulphuric acid disintegrates, and communicates a brown colour to the pure gutta, with evolution of sulphurous acid; after eight days' contact, the deep brown liquid, on dilution with water, becomes turbid, and furnishes a brown flocculent precipitate. Nitric acid, with a single equivalent of water, attacks the pure gutta with a lively effervescence, and the evolution of orange vapours of hyponitrous acid. Muriatic acid, in its saturated solution, slowly attacks the thin leaves of gutta, giving them a deep brown colour; at the end of eight days it becomes friable. The reaction of muriatic acid establishes an additional distinctive character between this proximate principle and the two others.

M. Payen has carefully examined the chemical and physical peculiarities of the three principles which he has discovered in gutta percha. These have, however, no interest for the manufacturer, and we refer the chemical student to M. Payen's Memoir.

The juice of Muddar has been proposed as a substitute for gutta percha, but we are not aware that it has in any manufacture taken its place. Dr. Falconer describes a new kind of gutta percha, which grows in the most southern British possession of the Merguin Islands, Indian Ocean.

If a solution of gutta percha in chloroform be mixed with 3 parts of ether, and exposed for some time to a temperature below 15°, the gutta percha is precipitated as a white powder, forming when washed and dried a soft white mass. On spreading this solution on a plate of glass, a skin is formed, resembling kid-glove leather, which becomes transparent on the application of heat. These films are beautifully white, if carefully prepared, and they have been employed in the manufacture of the finest kinds of artificial flowers.

In 1848, Dr. Faraday drew the attention of experimentalists to the highly insulating power of gutta percha, which not only possesses this property under ordinary circumstances, but likewise retains it under atmospheric conditions which would make the surface of glass a good conductor. This has led to its almost universal adoption as the insulator for the wires of the electrical telegraph. When buried in the earth, unless it is attacked by insects, or by a fungus, it retains its high insulatory power, and we have every reason for believing that gutta percha does not undergo a change when immersed in sea water. It has, however, been found, that when it has been exposed to the intense sunshine of India, it undergoes a remarkable change; oxygen is absorbed, the gutta percha loses its coherence, and at the same time its powers of insulation.

The quantity of gutta percha *imported* in 1857 was —

	Cwts.	Computed real value
Holland	4,228	£23,254
Phillipine Islands	263	1,446
British East Indies	12,087	66,479
Other parts	842	4,631

T. J. P.

GYPSUM. This natural production, which in its varieties is known as *sulphate of lime*, *alabaster*, *selenite*, *satin spar*, *gypa*, and *plaster of Paris*, has a composition of, sulphuric acid, 46·51; lime, 32·56; water, 20·93.

The *anhydrite* from Derby is a mineral like gypsum, but, as its name indicates, containing no water; its composition being, lime, 41·2; sulphuric acid, 58·8; this is also called *muriacite* and *tripe-stone*. It absorbs moisture and changes to gypsum. When gypsum is carefully burnt it loses its water of composition, and forms the well-known *plaster of Paris*.

The transparent varieties of gypsum are called *selenite*; its fine massive varieties are *alabaster*, and its fibrous kinds *satin spar*. There is another variety in small scales of a pearly lustre, known as *schaumkalk*. See ALABASTER.

H.

HACKLE. A flax comb. See FLAX.

HADE. A miner's term, used in Derbyshire and some of the northern counties, signifying the inclination or deviation from the vertical of any mineral vein or lode. *Hadings* signify that some parts of the vein incline, while others are vertical.

HÆMATINONE. A kind of glass used by the ancients for making ornamental vessels, mosaics, &c. It is described by Pliny, and has been found pretty abundantly in the excavations of Pompeii. This glass is of a beautiful red colour. It contains no tin or any other colouring matter except copper. All attempts of the moderns to imitate the antique *hæmatinone* have hitherto failed; the nearest approach is supposed to be the Italian porporino, which, however, differs from it in most respects.

HAIR (*Cheveu, Crin*, Fr.; *Haar*, Germ.) is of all animal products the one least liable to spontaneous change. It can be dissolved in water only at a temperature somewhat above 230° F., in a Papin's digester, but it appears to be partially decomposed by this heat, since some sulphuretted hydrogen is disengaged. By dry distillation, hair gives off sulphuretted gases, while the residuum contains sulphate of lime, common salt, much silica, with some oxide of iron and manganese. It is a remarkable fact that fair hair affords magnesia, instead of these latter two oxides. Horse-hair yields about 12 per cent. of phosphate of lime.

We have no recent analysis of hair. Vauquelin found nine different substances in black hair; in red hair, a red oil instead of a greenish-black one.

Hairs are tubular, their cavities being filled with a fat oil, having the same colour with themselves. Hair plunged in chlorine gas, is immediately decomposed and converted into a viscid mass; but when immersed in weak aqueous chlorine, it undergoes no change, except a little bleaching.

Living hairs are rendered black by applying to them for a short time a paste made by mixing litharge, slaked lime, and bicarbonate of potash, in various proportions, according to the shade of colour desired. The ordinary mode of dyeing human hair, is first to saturate the hair with the sulphide of potassium in solution; then, when this has been well absorbed and is partially dry, a solution of nitrate of silver is to be applied. By varying the proportions of the sulphide, and the strength of the silver solution, almost any tone of colour, from a brown to a black, can be produced.

The salts of silver, mercury, lead, bismuth, as well as their oxides, blacken hair, or make it of a dark violet, by the formation, most probably, of metallic sulphurets (*sulphides*).

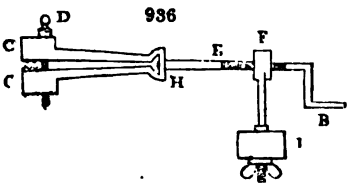
Hair as an object of manufactures is of two kinds, the *curly* and the *straight*. The former, which is short, is spun into a cord, and boiled in this state, to give it the tortuous springy form. The hairs of rabbits and hares are prepared for the hat-maker by a process called *sécretage*, so as to render them fit for felting. The skins with the hair still upon them are laid upon a table, and with a brush, made from the bristle of the wild boar, a solution of nitrate of mercury is applied many times in succession, till every part of the fur be equally touched, and till about two-thirds of the length of the hairs be moistened. The skins are then placed together to complete the impregnation, and put into a store-room. In drying there is a retraction of the hairs, and the required curling is produced. The long straight hair is woven into cloth for sieves, and also for ornamental purposes, as in the damask-hair cloth of chair bottoms. For this purpose the hair may be dyed in the following way:—

Forty pounds of tail hair, about 26 inches long, are steeped in lime water during twelve hours. Then a bath is made with a decoction of 20 pounds of logwood, kept boiling for three hours, after which time the fire is withdrawn from the boiler, and ten ounces of copperas are introduced, stirred about, and the hair is immersed, having been washed from the lime in river water. The hair should remain in this cooling bath for 24 hours, when the operation will be finished. Hair used for weaving is obtained principally from South America and from Russia. All the black and grey hair is dyed for the manufacture of black hair-cloth for covering furniture. White only can be dyed so as to produce what are called fancy colours, and great care is required in the process, which however, when well managed, produces good permanent colours.

The quality of hair-cloth, as well as the brilliancy and permanency of the colours, depend in a great degree on the nature of the warp, which may be either of cotton, linen, or worsted. Coloured hair-cloth, which is made at Worcester, Sheffield, and Paris, has been much used for fitting up the principal cabins of steam vessels, for covering sofas and chairs, and for railway carriages.

The looms for weaving hair differ from the common ones, only in the templet and the shuttle. Two templets of iron must be used to keep the stuff equably but lightly stretched. These templets, of which one is represented in *fig.* 936, are constructed in the shape of flat pincers; the jaws, C C, being furnished with teeth inside. A screw, D, binds the jaws together, and hinders the selvage from going inwards. Upon the side cross-beam of the loom, seen in section at I, a bolt is fixed which carries a nut F at its end, into which a screwed iron rod E enters, on one of whose ends is the handle B. The other extremity of the screw E is adapted by a washer and pin to the back of the pincers at the point H, so that by turning the handle to the right or the left, we draw onwards or push backwards the pincers and the stuff at pleasure. The warp of the web is made of black linen yarn. The weft is of hair, and it is thrown with a long hooked shuttle, or a long rod, having a catch hook at its end. The length of this shuttle is about 3 feet; its breadth half an inch, and its thickness one sixth. It is made of box-wood. The reed is of polished steel; the thread warps are conducted through it in the usual way. The workman passes this shuttle between the hairs of the warp with one hand, when the shed or shuttle way is opened by the treddles; a child placed on one side of the loom presents a hair to the weaver near the selvage, who catches it with the hook of his shuttle, and by drawing it out passes it through the warp. The hairs are placed in a bundle on the side where the child stands, in a chest filled with water to keep them moist, for otherwise they would not have the suppleness requisite to form a web. Each time that a hair is thrown across, the batten is driven home twice. The warp is dressed with paste in the usual way. The hair-cloth, after it is woven, is hot calendered to give it lustre. In the Great Exhibition of 1851, J. Bardoffsky (Russia) exhibited a collection of bowls, dishes, plates, &c., formed of the hair of the rabbit, hare, and other animals, which were felted and afterwards varnished. They had the appearance of papier maché, and were very light.

936



In 1857 we *imported* —	Cwt.	Computed real value.
Of cow, ox, bull, or elk hair - -	5,913 - -	- £ 27,495
Goat's hair - - - - - -	3,255,010 - -	- 393,314
Horse hair - - - - - -	21,389 - -	- 119,778

and of manufactures of hair or goat's wool, not made up, and wholly or in part made up, 233,200*l.*, as entered at computed real value.

HAIR BRUSHES, or PENCILS, for artists.

The *hair brushes* are manufactured with coarse hair, as that of the swine, the wild boar, the dog, &c. and these are usually attached, by binding with cord or by securing them with a piece of tin plate, to a wooden handle.

The *hair pencils* are composed of very fine hairs, as those of the sable, the miniver, the marten, the badger, and the polecat. These are usually mounted in a quill, but sometimes they are secured as in the former case with tinned iron.

The most essential quality of a good pencil is to form a fine point, so that all the hairs without exception may be united when they are moistened by laying them upon the tongue, or drawing them through the lips. When hairs present the form of an elongated cone in a pencil, their point only can be used. The whole difficulty consists, after the hairs are cleansed, in arranging them together so that all their points may lie in the same horizontal plane. We must wash the tails of the animals whose hairs are to be used, by scouring them in a solution of alum till they be quite free from grease, and then steeping them for 24 hours in luke-warm water. We next squeeze out the water by pressing them strongly from the root to the tip, in order to lay the hairs as smooth as possible. They are to be combed in the longitudinal direction, with a very fine-toothed comb, and finally wrapped up in fine linen, and dried. When perfectly dry, the hairs are seized with pincers, cut across close to the skin, and arranged in separate heaps, according to their respective lengths.

Each of these little heaps is placed separately, one after the other, in small tin pans with flat bottoms, with the tips of the hair upwards. On striking the bottom of the pan slightly upon a table, the hairs get arranged parallel to each other, and their delicate points rise more or less according to their lengths. The longer ones are to be picked out and made into so many separate parcels, whereby each parcel may be composed of equally long hairs. The perfection of the pencil depends upon this equality; the tapering point being produced simply by the attenuation of the tips.

A pinch of one of these parcels is then taken, of a thickness corresponding to the intended size of the pencil; it is set in a little tin pan, with its tips undermost, and

is shaken by striking the pan on the table as before. The root end of the hairs being tied by the fisherman's or seaman's knot, with a fine thread, it is taken out of the pan, and then hooped with stronger thread or twine; the knots being drawn very tight by means of two little sticks. The distance from the tips at which these ligatures are placed, is of course relative to the nature of the hair, and the desired length of the pencil. The base of the pencil must be trimmed flat with a pair of scissors.

Nothing now remains to be done but to mount the pencils in quill or tin-plate tubes, as above described. The quills are those of swans, geese, ducks, lapwings, pigeons, or larks, according to the size of the pencil. They are steeped during 24 hours in water, to swell and soften them, and to prevent the chance of their splitting when the hair brush is pressed into them. The brush of hair is introduced by its tips into the large end of the cut quill, having previously drawn them to a point with the lips, when it is pushed forwards with a wire of the same diameter, till it comes out at the other and narrower end of the quill.

The smaller the pencils, the finer ought the hairs to be. In this respect, the manufacture requires much delicacy of tact and experience.

HALIOTIS, *the sea ear shell.* A genus of molluscous animals belonging to the class Gasteropoda. These shells, possessing a fine nacre, are extensively used in the ornamentation of papier maché articles, and mother-of-pearl ornaments.

HALOGENE, is a term employed by Berzelius to designate those substances which form compounds of a saline nature by their union with metals; such are chlorine, iodine, bromine, fluorine, and cyanogen; the salts thus formed being called *haloid salts*, from their resemblance to common salt (NaCl), (ἅλς, sea salt, and εἶδος, form). Since the discovery of the compound halogene, Cyanogen, some chemists have been led to view all salts as under the type of haloid salts; assuming in the different acids certain compound halogens, as in sulphuric acid the halogene (SO^4); in nitric acid the halogene (NO^6) &c.; which in combination with hydrogen form the acids; the different salts being formed by the displacement of the hydrogen by the metal, as follows: sulphuric acid (HSO^4), sulphate of potash (KSO^4), nitric acid (HNO^6), nitrate of soda ($NaNO^6$), &c.—H. K. B.

HANDSPIKE. A strong wooden bar, used as a lever to move the windlass and capstan in heaving the anchor, or raising any heavy weights aboard ship. The handle is round, smooth, and somewhat taper. The other end is squared to fit the holes in the head of the capstan or the barrel of the windlass.

HARDENING. The processes by which metals are rendered harder than they are when they first leave the hands of the workman.

Some metals are hardened by hammering or rolling; but care is required not to carry this too far, as brittleness may be induced. Sudden cooling is had recourse to with some metals. Pure hammered iron appears after annealing to be equally soft, whether suddenly or slowly cooled; some of the impure kinds of malleable iron harden by immersion. Steel, however, receives by sudden cooling that extreme degree of hardness combined with tenacity, which places it so incalculably beyond every other material for the manufacture of cutting tools.

In hardening and tempering steel there are three things to be considered, namely, the means of heating the objects to redness, the means of cooling the same, and the means of applying the heat for *tempering*, or "letting them down." It is not possible in this work to enter into the manipulatory details of hardening steel for various purposes; the most valuable information on this subject is given in Holtzapffel's work on *Turning and Mechanical Manipulation.*

Steel pens are hardened by being heated in large quantities in iron trays within a furnace, and then plunged in an oily mixture; generally, they are likewise tempered in oil, or a composition, the boiling point of which is the same as the temperature suited to "letting them down."

Saws and springs are hardened in various compositions of oil, suet, wax, and other ingredients, "which however lose their hardening property after a few weeks' constant use." Steel plates are hardened occasionally by allowing water to fall on them when hot. See TRANSFER ENGRAVING.

Case hardening is the process by which wrought iron is first converted exteriorly into steel, and is subsequently hardened to that particular depth, leaving the central parts in their original condition of soft and fibrous iron. The principal agents used for case hardening are animal matters, as the hoofs, horns, bones, and skins of animals. The prussiate of potash, which is a compound of carbon and nitrogen, is also employed for case hardening. In principle it is the same as the animal substances. The iron is heated in the open fire to a dull red, and the prussiate is either sprinkled upon it or rubbed on in the lump; it is returned to the fire for a few minutes, and immersed in water. In the volume of Lardner's "Cyclopædia," *on Iron and Steel*, edited by Robert Hunt, the subjects of hardening and tempering are treated in a practical manner.

HARDNESS. (*Dureté*, Fr.; Härte, *Festigkeit*, Germ.) A hard body will *scratch* one that is softer than itself. This method of determining the hardness of minerals is employed by mineralogists. A good steel file is also used for trying the respective hardness of minerals.

Mohs introduced a scale of hardness, which shows the gradual increase in hardness through 10 minerals.

1. *Talc*; common laminated light green variety.
2. *Gypsum*; crystallised variety.
3. *Calcite*; transparent variety.
4. *Fluor spar*; crystalline variety.
5. *Apatite*; transparent variety.
6. *Felspar* (orthoclase); white cleavable variety.
7. *Quartz*; transparent.
8. *Topaz*; ditto.
9. *Sapphire*; cleavable varieties.
10. *Diamond.*

The following table, compiled by Dr. Ure for the early editions of his dictionary, will still be found very useful as representing, relatively, the hardness of the mineral named, although the numbers which express the degree of hardness do not agree with the scale of Mohs.

Substances.	Hardness.	Sp. Grav.	Substances.	Hardness.	Sp. Grav.
Diamond from Ormus	20	3·7	Sardonyx	12	2·6
Pink diamond	19	3·4	Occidental amethyst	11	2·7
Bluish diamond	19	3·3	Crystal	11	2·6
Yellowish diamond	19	3·3	Cornelian	11	2·7
Cubic diamond	18	3·2	Green jasper	11	2·7
Ruby	17	4·2	Reddish yellow do	9	2·6
Pale ruby from Brazil	16	3·5	Schorl	10	3·6
Deep blue sapphire	16	3·8	Tourmaline	10	3·0
Ditto, paler	17	3·8	Quartz	10	2·7
Topaz	15	4·2	Opal	10	2·6
Whitish topaz	14	3·5	Chrysolite	10	3·7
Ruby spinel	13	3·4	Zeolite	8	2·1
Bohemian topaz	11	2·8	Fluor	7	3·5
Emerald	12	2·8	Calcareous spar	6	2·7
Garnet	12	4·4	Gypsum	5	2·3
Agate	12	2·6	Chalk	3	2·7
Onyx	12	2·6			

HARDWARE. Under this term is comprehended the articles manufactured of any of the baser metals. See these respectively.

HARE WOOD. See SYCAMORE.

HARTSHORN, SPIRIT OF, is the old name for the solution of ammonia in water, the liquor ammonia of the London Pharmacopœia.

HASSOCK. A term given to a kind of sandstone produced in the quarries of Kentish Ragstone in Kent. When of good quality it is employed in building the interior walls of churches. The following is an analysis of Hassock by Dr. Plomby, of Maidstone:—

Carbonate of lime	53
Alumina	4
Oxide of iron	8
Silica	32
Small quantities of phosphate of lime, soda, magnesia, chlorine and sulphuric acid	3
	100

HAT MANUFACTURE. (*L'art de Chapelier*, Fr.; *Hutmacherkunst*, Germ.) Hat is the name of a covering for the head worn by both sexes, but principally by men.

As the art of making hats does not involve the description of any curious machinery, or any interesting processes, we shall not enter into very minute details upon the subject. It will be sufficient to convey to the reader a general idea of the methods employed in this manufacture.

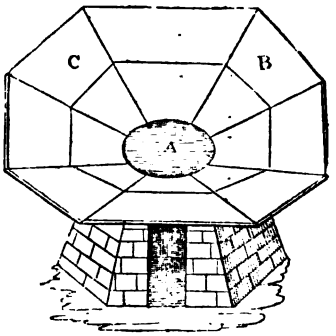
The materials used in making stuff hats are the furs of hares and rabbits freed from the long hair, together with wool and beaver. The beaver is reserved for the finer

hats. The fur is first laid upon a hurdle made of wood or wire, with longitudinal openings; and the operator, by means of an instrument called the bow, (which is a piece of elastic ash, six or seven feet long, with a catgut stretched between its two extremities, and made to vibrate by a bowstick,) causes the vibrating string to strike and play upon the fur, so as to scatter the fibres in all directions, while the dust and filth descend through the grids of the hurdle.

After the fur is thus driven by the bow from one end of the hurdle to the other, it forms a mass called a *bat*, which is only half the quantity sufficient for a hat. The bat or *capade* thus formed is rendered compact by pressing it down with the *hardening skin* (a piece of half-tanned leather), and the union of the fibres is increased by covering them with a cloth, while the workman presses them together repeatedly with his hands. The cloth being taken off, a piece of paper, with its corners doubled in, so as to give it a triangular outline, is laid above the bat. The opposite edges of the bat are then folded over the paper, and being brought together and pressed again with the hands, they form a conical cap. This cap is next laid upon another bat, ready hardened, so that the joined edges of the first bat rest upon the new one. This new bat is folded over the other, and its edges joined by pressure as before; so that the joining of the first conical cap is opposite to that of the second. This compound bat is now wrought with the hands for a considerable time upon the hurdle between folds of linen cloth, being occasionally sprinkled with clear water, till the hat is *basoned*, or rendered tolerably firm.

The cap is now taken to a wooden receiver, like a very flat mill-hopper, consisting of eight wooden plains, sloping gently to the centre, which contains a kettle filled with water acidulated with sulphuric acid. The technical name of this vessel is the *battery*. It consists of a kettle A, *fig.* 932; and of the planks, B, C, which are sloping planes, usually eight in number, one being allotted to each workman. The half of each plank next the kettle is made of lead, the upper half of mahogany. In this liquor the hat is occasionally dipped, and wrought by the hands, or sometimes with a roller, upon the sloping planks. It is thus fulled or thickened during four or five hours; the knots or hard substances are picked out by the workman, and fresh felt is added by means of a wet brush to those parts that require it. The beaver is applied at the end of this operation. In the manufacture of beaver hats, the grounds of beer are added to the liquor in the kettle.

937



Stopping, or thickening the thin spots, seen by looking through the body, is performed by daubing on additional stuff with successive applications of the hot acidulous liquor from a brush dipped into the kettle, until the body be sufficiently shrunk and made uniform. After drying, it is stiffened with varnish composition rubbed in with a brush; the inside surface being more copiously imbued with it than the outer; while the brim is peculiarly charged with the stiffening.

When once more dried, the body is ready to be *covered*, which is done at the *battery*. The first cover of beaver or napping, which has been previously *bowed*, is strewed equably over the body, and patted on with a brush moistened with the hot liquor, until it gets incorporated; the cut ends towards the root, being the points which spontaneously intrude. The body is now put into a coarse hair cloth, then dipped and rolled in the hot liquor, until the root ends of the beaver are thoroughly worked in. This is technically called rolling off, or *roughing*. A strip for the brim, round the edge of the inside, is treated in the same way; whereby everything is ready for the second cover (of beaver), which is incorporated in like manner; the rolling, &c. being continued, till a uniform, close, and well-felted hood is formed.

The hat is now ready to receive its proper shape. For this purpose the workman turns up the edge or brim to the depth of about 1½ inch, and then returns the point of the cone back again through the axis of the cap, so as to produce another inner fold of the same depth. A third fold is produced by returning the point of the cone, and so on till the point resembles a flat circular piece having a number of concentric folds. In this state it is laid upon the plank, and wetted with the liquor. The workman pulls out the point with his fingers, and presses it down with his hand, turning it at the same time round on its centre upon the plank, till a flat portion, equal to the crown of the hat, is rubbed out. This flat crown is now placed upon a block, and, by pressing a string called a *commander*, down the sides of the block, he forces the parts adja-

cent to the crown, to assume a cylindrical figure. The brim now appears like a puckered appendage round the cylindrical cone; but the proper figure is next given to it, by working and rubbing it. The body is rendered waterproof and stiff by being imbued with a varnish composed of shellac, sandarach, mastic, and other resins dissolved in alcohol or naphtha.

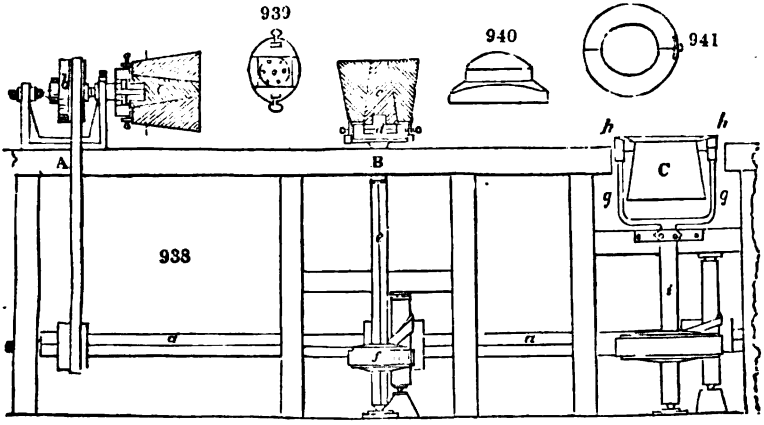
The hat being dried, its nap is raised or loosened with a wire brush or card, and sometimes it is previously pounced or rubbed with pumice, to take off the coarser parts and afterwards rubbed over with seal skin. The hat is now tied with packthread upon its block, and is afterwards dyed.

The dyed hats are now removed to the stiffening shop. Beer grounds are next applied on the inside of the crown, for the purpose of preventing the glue from coming through; and when the beer grounds are dried, glue (gum Senegal is sometimes used), a little thinner than that used by carpenters, is laid with a brush on the inside of the crown, and the lower surface of the brim.

The hat is then softened by exposure to steam, on the steaming basin, and is brushed and ironed till it receives the proper gloss. It is lastly cut round at the brim by a knife fixed at the end of a gauge, which rests against the crown. The brim, however, is not cut entirely through, but is torn off so as to leave an edging of beaver round the external rim of the hat. The crown being tied up in a gauze paper, which is neatly ironed down, is then ready for the last operations of lining and binding.

The furs and wools of which hats are manufactured contain in their early stage of preparation, *hemps* and *hairs*, which must be removed in order to produce a material for the better description of hats. This separation is effected by a sort of winnowing machine, which wafts away the finer and lighter parts of the furs and wools from the coarser.

The annexed figures represent Mr. Ollerenshaw's machine, generally employed for ironing hats. *Fig.* 938 is the frame-work or standard upon which three of these



lathes are mounted, as A, B, C. The lathe A is intended to be employed when the crown of the hat is to be ironed. The lathe B, when the flat top, and the upper side of the brim is ironed, and lathe C, when its under side is ironed; motion being given to the whole by means of a band passing from any first mover (as a steam-engine, waterwheel, &c.) to the drum on the main shaft *a a*. From this drum a strap passes over the rigger *b*, which actuates the axle of the lathe A. On to this lathe a sort of chuck is screwed, and to the chuck the block *c* is made fast by screws, bolts, or pins. This block is represented in section, in order to show the manner in which it is made, of several pieces held fast by the centre wedge-piece, as seen at *fig.* 939.

The hat-block being made to turn round with the chuck, at the rate of about twenty turns per minute, but in the opposite direction to the revolution of an ordinary turning lathe, the workman applies his hot iron to the surface of the hat, and thereby smooths it, giving a beautiful glossy appearance to the beaver; he then applies a plush cushion, and rubs round the surface of the hat while it is still revolving. The hat, with its block, is now removed to the lathe B, where it is placed upon the chuck *d*, and made to turn in a horizontal direction, at the rate of about twenty revolutions per minute, for the purpose of ironing the flat-top of the crown. This lathe B moves upon an upright shaft *e*, and is actuated by a twisted band passing from the main shaft round the rigger *f*. In order to iron the upper surface of the brim, the block *c* is removed from

the lathe, and taken out of the hat, when the block *fig.* 940 is mounted upon the chuck *d*, and made to turn under the hand of the workman, as before.

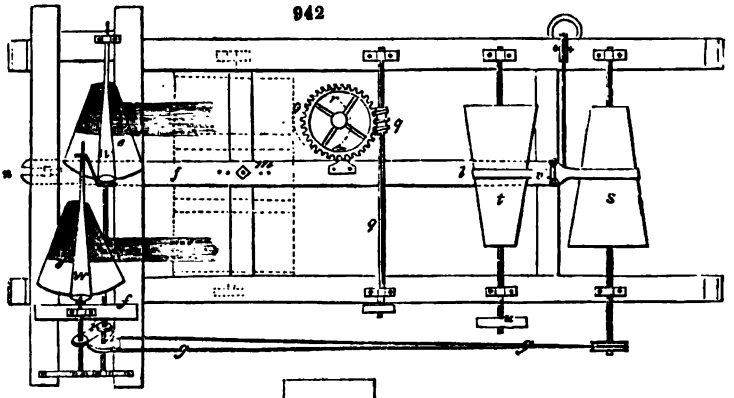
The hat is now to be removed to the lathe c, where it is introduced in an inverted position, between the arms *g g* supporting the rim *h h*, the top surface of which is shown at *fig.* 941. The spindle *i* of the lathe turns by similar means to the last, but slower; only ten turns per minute will be sufficient. The workman now smooths the under side of the brim, by drawing the iron across it, that is from the centre outwards. The hat is then carefully examined, and all the burs and coarse hairs picked out, after which the smoothing process is performed as before, and the dressing of the hat is complete. This description of the manufacture of the beaver hat has been retained, though it is now but little practised, the silk hat having taken its place.

Silk hats, for several years after they were manufactured, were liable to two objections; first, the body or shell over which the silk covering is laid, was, from its hardness, apt to hurt the head; second, the edge of the crown being much exposed to blows, the silk nap soon got abraded, so as to lay bare the cotton foundation, which is not capable of taking so fine a black die as the silk; whence the hat assumed a shabby appearance. Messrs. Mayhew and White, of London, proposed to remedy these defects, by making the hat body of stuff or wool, and relieving the stiffness of the inner part round the brim, by attaching a coating of beaver upon the under side of the brim, so as to render the hat pliable. Round the edge of the tip or crown, a quantity of what is called stop wool is to be attached by the ordinary operation of bowing, which will render the edge soft and elastic. The hat is to be afterwards dyed of a good black colour, both outside and inside; and being then properly stiffened and blocked, is ready for the covering of silk.

The plush employed for covering silk hats, is a raised nap or pile woven usually upon a cotton foundation; and the cotton, being incapable of receiving the same brilliant black dye as the silk, renders the hat apt to turn brown whenever the silk nap is partially worn off. To counteract this evil, the foundation of the plush is now frequently made entirely of silk. To these two improvements, now pretty generally introduced, the present excellence of the silk hats may be ascribed.

Fig. 942 is a side view of the carding engine, employed in preparing the silk for

942



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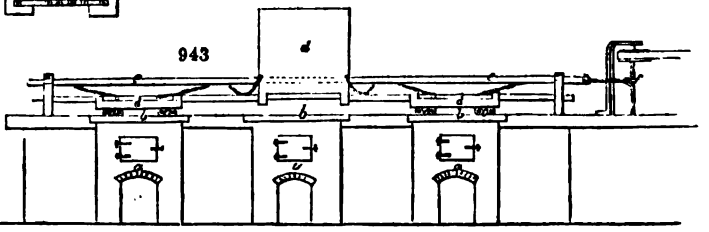


hats, with a horizontal plan or view of the lower part of the carding machine, showing the operative parts of the winding apparatus, as connected to the carding engine. The doffer cylinder is covered with fillets of wire cards, such as are usually employed in carding engines, and these fillets are divided into two, three, or more spaces extending round the periphery of the cylinder, the object of which division is to separate the sliver into two, three, or more breadths, which are to be conducted to and wound upon distinct blocks, for making so many separate hats or caps.

The principal cylinder of the carding engine, is made to revolve by a rigger upon its axle, actuated by a band from any first mover as usual, and the subordinate rollers or cylinders belonging to the carding engine, are all turned by pulleys, and bands, and gear, as in the ordinary construction.

The wool or other material is supplied to the feeding cloth, and carried through the engine to the doffer cylinder, as in other carding engines; the doffer comb is actuated by a revolving crank in the common way, and by means of it the slivers are taken from the doffer cylinder, and thence received on to the surfaces of the blocks *e e*. These blocks, of which two only are shown to prevent confusion, are mounted upon axles, supported by suitable bearings, in a carriage *f f*, and are made to revolve by means of a band *g g*, leading from a pulley on the axle of a conical drum beneath. The band *g* passes over a pulley *h*, affixed to the axle of one of the blocks, while another pulley *i*, upon the same axle, gives motion, by means of a band, to as many other blocks as are adapted to the machine.

As it is necessary in winding the slivers on to the blocks, to cross them in different directions, and also to pass the sliver over the hemispherical ends of the blocks, in order that the wool or other material may be uniformly spread over the surface in forming the cap or hood for the shell or foundation of the intended hat, the carriage *f*, with the blocks, is made to traverse to and fro in lateral directions upon rollers at each end.

This alternating motion of the carriage is caused by a horizontal lever *l l* (seen in the horizontal view *fig.* 942), moving upon a fulcrum pin at *m*, which lever is attached to the carriage at one extremity *n*, and at the other end has a weighted cord which draws the side of this lever against a cam wheel *o*. This cam is made to revolve by means of a band and pulley, which turns the shaft and endless screw *q*, and this endless screw, taking into a toothed wheel *r*, on the axle of the cam *o*, causes the cam to revolve, the periphery of which cam running against a friction roller on the side of the lever *l*, causes the lever to vibrate, and the carriage *f f*, attached to it, to traverse to and fro upon the supporting rollers, as described. By these means the slivers are laid in oblique directions (varying as the carriage traverses) over the surface of the blocks.

The blocks being conically formed, or of other irregular figures, it is necessary, in order to wind the slivers with uniform tension, to vary their speed according to the diameter of that part of the block which is receiving the sliver. This is effected by giving different velocities to the pulley on the axle of the conical drum *s*, corresponding with *e*. There is a similar conical drum *t*, placed in a reverse position in the lower part of the frame, which is actuated by a band from any convenient part of the machine passing over a pulley *u*, upon the axle of *t*. From the drum *t*, to the drum *s*, there is a band *v*, which is made to slide along the drums by the guidance of two rollers at the end of the lever *l*.

It will now be seen that when the larger diameter of the cam wheel *o* forces the lever outwards, the band *v* will be guided on to the smaller part of the conical drum *t*, and the larger part of *s*, consequently the drum *s* will at this time receive its slowest motion, and the band *g* will turn the blocks slower also; the reverse end of the lever *l*, having by the same movement slidden the carriage into that position which causes the slivers to wind upon the larger diameter of the blocks.

When the smaller diameter of the cam is acting against the side of the lever, the weighted cord draws the end of the lever to the opposite side, and the band *v* will be guided on to the larger part of the cone *t*, and the smaller part of the cone *s*; consequently, the quicker movement of the band *g* will now cause the blocks *e e* to revolve with a corresponding speed. The carriage *f* will also be moved upon its rollers to the reverse side, and the sliver of wool or other material be now wound upon the smaller parts and ends of the blocks, at which time the quicker rotation of the blocks is required. It may be here observed, that the cam wheel *o* should be differently formed according to the different shaped blocks employed, so as to produce the requisite movements of the lever and carriage suited thereto.

It only remains to state that there are two heavy conical rollers *w w*, bearing upon the peripheries of the blocks *e e*, which turn loosely upon their axles by the friction of contact, for the purpose of pressing the slivers of wool or other material on the blocks as it comes from the doffer cylinder of the carding engine, and when the blocks have been coated with a sufficient quantity of the sliver, the smaller end of the pressing rollers is to be raised, while the cap is withdrawn from the block. The process being continued as before, the formations of other bodies or caps is effected in the manner above described.

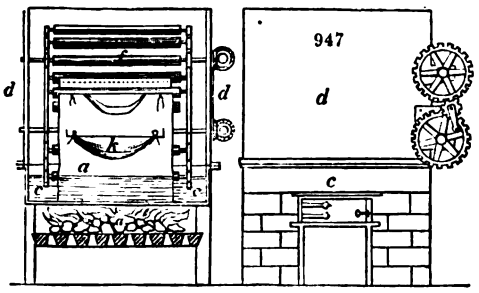
After the caps or bodies of hats, &c. are formed in the above described machine, they are folded in wet cloths, and placed upon heated plates, where they are rolled under pressure, for the purpose of being hardened. *Fig.* 938 represents the front of three

furnaces *a a a*, the tops of which are covered with iron plates *b b b*. Upon these plates, which are heated by the furnace below, or by steam, the bodies wrapped in the wet cloths *c c c*, are placed, and pressed upon by the flaps or covers *d d d*, sliding upon guide rods, to which flaps a traversing motion is given, by means of chains attached to an alternating bar *e e*. This bar is moved by a rotary crank *f*, which has its motion by pulleys from any actuating power. When any one of the flaps is turned up to remove the bodies from beneath, the chains hang loosely, and the flap remains stationary.

These caps or hat bodies, after having been hardened in the manner above described, may be felted in the usual way by hand, or they are felted in a fulling mill by the usual process employed for milling cloths, except that the hat bodies are occasionally taken out of the fulling mill, and passed between rollers, for the purpose of rendering the felt more perfect.

Mr. Carey, of Basford, obtained a patent in October, 1834, for an invention of certain machinery to be employed in the manufacture of hats, which is ingenious and seems to be worthy of notice in this place. It consists in the adaptation of a system of rollers, forming a machine, by means of which the operation of roughing or plaiting of hats, may be performed; that is, the beaver or other fur may be made to attach itself, and work into the felt or hat body, without the necessity of the ordinary manual operations.

944



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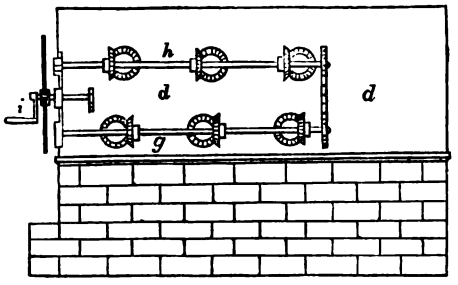
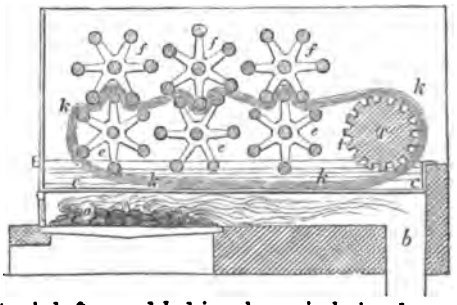


946



The accompanying drawings represent the machine in several views, for the purpose of showing the construction of all its parts. *Fig.* 944 is a front elevation of the machine; *fig.* 945 is a side elevation of the same; *fig.* 946 is a longitudinal section of the machine; and *fig.* 947 is a transverse section; the similar letters indicating the same parts in all the figures.

Upon a brick or other suitable base, a furnace or fireplace *a*, is made, having a descending flue *b*, for the purpose of carrying away the smoke. A pan or shallow vessel *c c*, formed of lead, is placed over the furnace; which vessel is intended to contain a sour liquor, as a solution of vitriolic acid and water. On the edge of this pan is erected a wooden casing *d d d*, which encloses three sides, leaving the fourth open for the purpose of obtaining access to the working apparatus within. A series of what may be termed lantern rollers, *e e e*, is mounted on axles turning in the side casings; and another series of similar lantern rollers, *f f f*, is in like manner mounted above. These lantern rollers are made to revolve by means of bevel pinions, fixed on the ends of their axles, which are turned by similar bevel wheels on the lateral shafts *g*, and *h*, driven by a winch, *i*, and gear, as shown in *figs.* 944 and 945.

Having prepared the bodies of the hats, and laid upon their surfaces the usual coatings of beaver, or other fur, when so prepared they are to be placed between hair

cloths, and these hair cloths folded within a canvas or other suitable wrapper. Three or more hats being thus enclosed in each wrapper, the packages are severally put into bags or pockets in an endless band of sackcloth, or other suitable material; which endless band is extended over the lantern rollers in the machine.

In the first instance, for the purpose of merely attaching the furs to the felts (which is called slicking, when performed by hand), Mr. Carey prefers to pass the endless band *k k k*, with the covered hat bodies, over the upper series *f f f*, of the lantern rollers, in order to avoid the inconvenience of disturbing the fur, which might occur from subjecting them to immersion in the solution contained in the pan, before the fur had become attached to the bodies.

After this operation of slicking has been effected, he distends the endless band *k k k*, over the lower series of lantern rollers *e e e*, and round a carrier roller *l*, as shown in *fig.* 946; and having withdrawn the hat bodies for the purpose of examining them, and changing their folds, he packs them again in a similar way in flannel, or other suitable cloths, and introduces them into the pockets or bags of the endless bands, as before.

On putting the machinery in rotatory motion in the way described, the hats will be carried along through the apparatus, and subjected to the scalding solution in the pan, as also to the pressure, and to a tortuous action between the ribs of the lantern rollers, as they revolve, which will cause the ends of the fur to work into the felted bodies of the hats, and by that means permanently to attach the nap to the body; an operation which when performed by hand, is called rolling off.

A varnish made by dissolving shellac, mastic, sandarac, and other resins in alcohol, or the naphtha of wood vinegar, is generally employed as the stiffening and waterproof ingredient of hat bodies. A solution of caoutchouc is often applied to whalebone and horse-hair hat bodies.

The following recipe has been prescribed as a good composition for stiffening hats: four parts of shellac, one part of mastic, one half of a part of turpentine, dissolved in five parts of alcohol, by agitation and subsequent repose, without the aid of heat. This stiffening varnish should be applied quickly to the body or foundation with a soft oblong brush, in a dry and rather warm workshop; the hat being previously fitted with its inside turned outwards upon a block. The body must be immediately afterwards taken off, to prevent adhesion.

Another method of proceeding is, first to dissolve the gums by agitation in twice the due quantity of spirits, whether of wood or wine, and then, after complete solution, draw off one half the spirit in a still, so as to bring the stiffening to a proper consistency. No sediment subsequently appears on diluting this solution, however much it may be done.

Both the spirit and alkali stiffenings for hats made by the following two recipes, have been tried by some of the first houses in the trade, and have been much approved of:—

Spirit Stiffening.

7 pounds of orange shellac.
2 pounds of gum sandarac,
4 ounces of gum mastic
Half a pound of amber resin.
1 pint of solution of copal.
1 gallon of spirit of wine or wood naphtha.

The shellac, sandarac, mastic, resin, are dissolved in the spirit, and the solution of copal is added last.

Alkali Stiffening.

7 pounds of common block shellac.
1 pound of amber resin.
4 ounces of gum thus.
4 ounces of gum mastic
6 ounces of borax.
Half a pint of solution of copal.

The borax is first dissolved in a little warm water (say 1 gallon); this alkaline liquor is now put into a copper pan (heated by steam), together with the shellac, resin, thus, and mastic, and allowed to boil for some time, more warm water being added occasionally until it is of a proper consistence.

Hat-Dyeing.— The ordinary bath for dyeing hats employed by the London manufacturers consists, for 12 dozen, of—

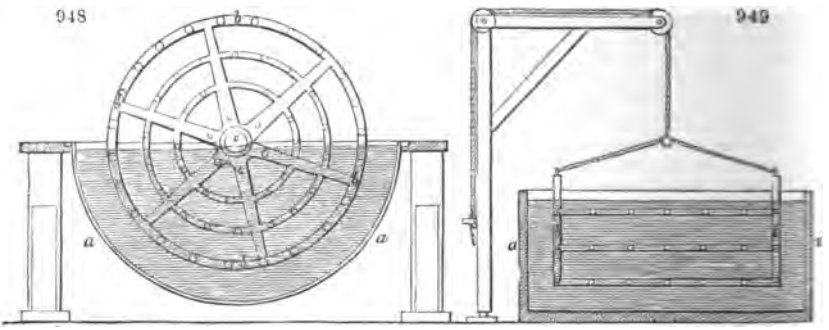
144 pounds of logwood;
12 pounds of green sulphate of iron, or copperas;
7½ pounds of verdigris.

The copper is usually made of a semi-cylindrical shape, and should be surrounded with an iron jacket or case, into which steam may be admitted, so as to raise the temperature of the interior bath to 190° F., but no higher, otherwise the heat is apt to affect the stiffening varnish, called the gum, with which the body of the hat has been imbued. The logwood having been introduced and digested for some time, the copperas and verdigris are added in successive quantities, and in the above proportions, along with every successive two or three dozens of hats, suspended upon the dipping machine. Each set of hats, after being exposed to the bath with occasional airings during 40 minutes, is taken off the pegs, and laid out upon the ground to be more completely blackened by the peroxidisement of the iron with the atmospheric oxygen. In 3 or 4 hours the dyeing is completed. When fully dyed, the hats are well washed in running water.

Mr. Buffum states that there are four principal objects accomplished by his patent invention for dyeing hats:—

1. In the operation;
2. The production of a better colour;
3. The prevention of any of the damages to which hats are liable in the dyeing;
4. The accomplishment of the dyeing process in a much shorter time than by the usual methods, and consequently lessening the injurious effects of the dye-bath upon the texture of the hat.

Fig. 948 shows one method of constructing the apparatus. *a a* is a semi-cylindrical

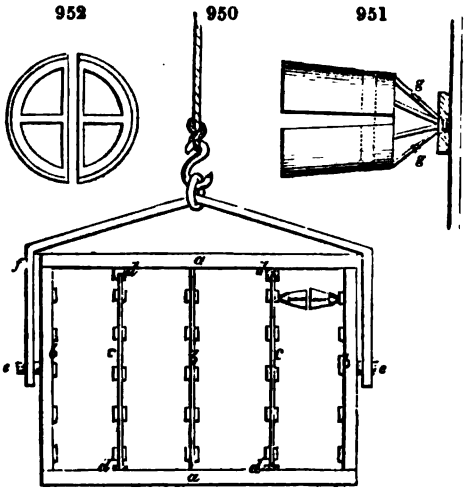


snaped copper vessel, with flat ends, in which the dyeing process is carried on. *b b b* is a wheel with several circular rims mounted upon arms, which revolve upon an axle *c*. In the face of these rims a number of pegs or blocks are set at nearly equal distances apart, upon each of which pegs or blocks it is intended to place a hat, and as the wheel revolves, to pass it into and out of the dyeing liquor in the vat or copper. This wheel may be kept revolving with a very slow motion, either by gear connecting its axle, *c*, with any moving power, or it may be turned round by hand, at intervals of ten minutes; whereby the hats hung upon the pegs will be alternately immersed for the space of ten minutes in the dyeing liquor, and then for the same space exposed to the atmospheric air. In this way, the process of dyeing, it is supposed, may be greatly facilitated and improved, as the occasional transition from the dye vat into the air, and from the air again into the bath, will enable the oxygen of the atmosphere to strike the dye more perfectly and expeditiously into the materials of which the hat is composed, than by a continued immersion in the bath for a much longer time.

A variation in the mode of performing this process is suggested, and the apparatus *fig.* 949 is proposed to be employed. *a a* is a square vat or vessel containing the dyeing liquor; *b b* is a frame or rack having a number of pegs placed in it for hanging the hats upon, which are about to be dyed, in a manner similar to the wheel above described. This frame or rack is suspended by cords from a crane, and may in that way be lowered down with the hats into the vat, or drawn up and exposed in the air; changes which may be made every 10 or 20 minutes.

Mr. William Hodge's patent improvements in hat dyeing, partly founded upon an invention of Mr. Bowler, consist, first in causing every alternate frame to which the suspenders or blocks are to be attached, to slide in and out of grooves, for the purpose of more easily removing the said suspenders when required. *Fig.* 950, represents the improved dyeing frame, consisting of two circular rims, *a a*, which are connected together at top and bottom, by three fixed perpendicular bars or the frame-work *b b b*. Two other perpendicular frames, *c c*, similar to the former, slide in grooves, *d d d d*,

fixed to the upper and lower rims. These grooves have anti-fraction rollers in them for the purpose of making the frames *c c*, to slide in and out more freely. The suspenders or substitutes for blocks, by these means, may be more easily got at by drawing out the frames *c c*, about half way, when the suspenders, which are attached to the frames with the hats upon them, may be easily reached, and either removed or altered in position; and when it is done on one side, the sliding-frame may be brought out on the other, and the remaining quantity of "suspenders" undergo the same operation.



The patentee remarks, that it is well known to all hat dyers, that after the hats have been in the dyeing liquor some time, they ought to be taken out and exposed to the action of the atmospheric air, when they are again immersed in the copper, that part of the hat which was uppermost in the first immersion, being placed downwards in the second. This is done for the purpose of obtaining an uniform and regular dye. The patentee's mode of carrying this operation into effect, is shown in the figure: *e e* are pivots for the dyeing-frame to turn upon, which is supported by the arms *f*, from a crane above. The whole apparatus may be raised up or lowered into the copper by means of the crane or other mechanism. When the dyeing-frame is raised out of the copper, the whole of the suspenders or blocks are reversed, by turning the apparatus over upon the pivots *e e*, and thus the whole surfaces of the hats are equally acted upon by the dyeing material.

It should be observed, that when the dyeing-frame is raised up out of the copper, it should be tilted on one side, so as to make all the liquor run out of the hats, as also to cause the rims of the hats to hang down, and not stick to the body of the hat, or leave a bad place or uneven dye upon it. The second improvement described by the patentee, is the construction of "suspenders," to be substituted instead of the ordinary blocks.

These "suspenders" are composed of thin plates of copper, bent into the required form, that is, nearly resembling that of a hat block, and made in such a manner as to be capable of contraction and expansion to suit different sized hats, and keep them distended, which may be altered by the workman at pleasure, when it is required to place the hats upon them, or remove them therefrom. The dyeing-frame at *fig.* 950, is shown with only two of these "suspenders," in order to prevent confusion. One of these suspenders is represented detached at *fig.* 951, which exhibits a side view; and *fig.* 952, a front view of the same. It will be seen by reference to the figure, that the suspenders consist of two distinct parts, which may be enlarged or collapsed by a variety of means, and which means may be suggested by any competent mechanic. The two parts of the suspenders are proposed to be connected together by arms *g g*, and at the junction of these arms a key is connected for turning them round when required. It will be seen on reference to the front view, *fig.* 952, that the "suspenders" or substitutes for blocks are open at the top or crown part of the hat; this is for the purpose of allowing the dyeing liquor to penetrate.

From the mixture of copperas and verdigris employed in the hat dye, a vast quantity of an ochreous muddy precipitate results, amounting to no less than 25 per cent. of the weight of the copperas. This iron mud forms a deposit upon the hats, which not only corrodes the fine filaments of the beaver, but causes both them and the felt stuff to turn speedily of a rusty brown. There is no process in the whole circle of our manufactures so barbarous as that of dyeing stuff hats. No ray of chemical science seems hitherto to have penetrated the dark recesses of their dye shops. Some hatters have tried to remove this corrosive brown ochre by a bath of dilute sulphuric acid, and then counteract the evil effect of the acid upon the black dye by an alkaline bath; but with a most unhappy effect. Hats so treated are most deceptive and

unprofitable; as they turn of a dirty brown hue when exposed for a few weeks to sunshine and air.

The annual value of the hats manufactured at present in the United Kingdom is estimated at 3,000,000*l.* sterling. The quantity *exported* in 1857, was 149,946 dozens, valued at 292,198*l.*

HAWTHORN. (*Epine Blanche*, Fr.; *Weissdorn*, Germ.) *Cratægus oxycantha*, Linn. This shrub has a hard whitish wood, but as it is small and difficult to work it is not much used.

HAYESSINE. A borate of lime, which is found abundantly on the western coast of America, so called from its discoverer. It has been introduced for use in our glass manufacture, and is used by our potters. See BORAX.

HAZEL. (*Hoisetier*, Fr.; *Haselstande*, Germ.) The *Corylus avellana*, a small underwood, used a little in turnery and for the manufacture of toys.

HAZEL. A north of England term for a hard grit.

HAZEL MOULD. The name given in Hampshire to a light loamy soil.

HEARTH (*Foyer*, Fr.; *Heerde*, Germ.) is the flat or hollow space in a smelting furnace upon which the ore and fluxes are subjected to the influence of flame. See COPPER, IRON, METALLURGY, &c.

HEARTHSTONE. A soft stone employed for whitening door steps, &c. An enormous quantity of hearthstones are brought to London from the quarries at Godstone.

HEAT. The Force or Principle upon which the conditions, relatively, of solid, fluid, and aeriform states depend. That which produces the sensation of warmth.

The discussion of the habitudes of heat with the different kinds of matter belongs to physico-chemical science, and will be treated of in *Ure's Dictionary of Chemistry*. It will suffice in this place, to state succinctly those laws which have, more directly, a bearing on any of our manufacturing processes.

Heat and motive power are mutually convertible, and heat requires for its production, and produces by its disappearance, motive power in the proportion of 772 foot-pounds for each Fahrenheit unit of heat.—Rankine.

This unit of heat has been established by Dr. Joule to be the amount of heat required to raise the temperature of one pound of liquid water by one degree of Fahrenheit. A falling weight, or any other mode of motion, produces a definite quantity of heat according to this law.

If the total actual heat of a homogeneous and uniformly hot substance be conceived to be divided into any numbers of equal parts, the effect of those parts in causing work to be performed will be equal. — Rankine.

Or in other words, of a given equivalent of heat, from whatever source produced, the work which it can effect is always an equal and constant quantity.

Heat may be produced by friction, as we see in the development of it, powerfully, in the axles of railway carriages insufficiently lubricated. By the attrition of two pieces of wood ignition can be obtained.

Heat is developed in the mixture of bodies of different densities, such as spirits of wine and water, or sulphuric acid and water, there being a diminution of volume in each case.

Heat is produced by many conditions of chemical combination, in numerous cases so energetically as to produce intense combustion and even explosion.

Heat is obtained by combustion for our ordinary manufacturing processes, and domestic uses. This is a chemical union of one body with another, as carbon with oxygen; but to effect this, an excitant appears necessary or a continually increasing excitement of the energy upon which heat depends, as, the application of flame in one case and the phenomena of spontaneous combustion in another.

Electricity by its disturbing power, developes heat, and this all important force is also rendered manifest by the processes of vitality (vital or nervous force).

Dr. Joule has clearly shown, that whatever may be the source of heat, a certain fixed elevation of temperature is produced by a given amount of mechanical, chemical, electrical, or vital disturbance, and that the mechanical value of the *cause* producing the heat is exactly represented by the mechanical *effect* obtained.

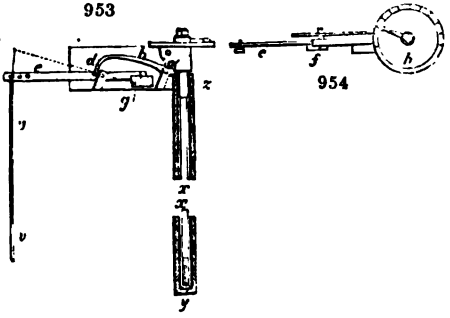
For a full discussion of this important point, see the Memoirs of Joule, of Thomson, and of Rankine, in the Philosophical Transactions of London and Edinburgh. The applications of heat will be found under the proper heads. See also SPHEROIDAL STATE.

HEAT-REGULATOR, or THERMOSTAT. The name given by M. Bonnemain to an ingenious apparatus for regulating the temperature of his incubating stove rooms. See INCUBATION, ARTIFICIAL, for the manner of applying the Heat-Regulator.

The construction of the regulator is founded upon the unequal dilatation of different metals by the same degree of heat. A rod of iron *x*, *fig.* 953, is tapped at its lower

end into a brass nut *y*, enclosed in a leaded box or tube, terminated above by a brass collet *z*. This tube is plunged into the water of the boiler, alongside of the smoke-pipe. *Fig.* 954, is a bird's-eye view of the dial, &c. The expansion of the lead being more than the iron for a like degree of temperature, and the rod enclosed within the tube being less easily warmed, whenever the heat rises to the desired pitch, the elongation of the tube puts the collet *z* in contact with the heel, *a*, of the bent lever *a*, *b*, *d*; thence the slightest increase of heat lengthens the tube anew, and the collet lifting the heel of the lever, depresses the other end *d* through a much greater space, on account of the relative lengths of its legs. This movement operates near the axis of a balance-bar *e*, sinks one end of this, and thereby increases the extent of the movement, which is transmitted directly to the iron skewer *v*. This pushing down a swing register diminishes or cuts off the access of air to the fire-place. The combustion is thereby obstructed, and the temperature falling by degrees, the tube shrinks and disengages the heel of the lever. The counterpoise *g*, fixed to the balance beam *e*, raises the other extremity of this beam by raising the end *d* of the lever as much as is necessary to make the heel bear upon the collet of the tube. The swing register acted upon by this means, presents a greater section to the passage of the air; whence the combustion is increased. To counterbalance the effect of atmospheric changes, the iron stem which supports the regulator is terminated by a dial disc, round the shaft of the needle above *h*, *fig.* 954; on turning this needle, the stem below it turns, as well as a screw at its under end, which raises or lowers the leaden tube. In the first case the heel falls, and opens the swing register, whence a higher temperature is required to shut it, by the expansion of the tube. We may thus obtain a regularly higher temperature. If, on the contrary, we raise the tube by turning the needle in the other direction, the register presents a smaller opening, and shuts at a lower temperature; in this case we obtain a regularly lower temperature. It is therefore easy, says M. Bonnemain, to determine *à priori* the degree of temperature to be given to the water circulating in the stove pipes. In order to facilitate the regulation of the apparatus, he graduated the disc dial, and inscribed upon its top and bottom, the words Strong and Weak heat.

953



THERMOSTAT, is the name of an apparatus for regulating temperature, in vaporisation, distillations, heating baths or hothouses, and ventilating apartments, &c.; for which I obtained a patent in the year 1831. It operates upon the physical principle, that when two thin metallic bars of different expansibilities are riveted or soldered facewise together, any change of temperature in them will cause a sensible movement of flexure in the compound bar, to one side or other; which movement may be made to operate, by the intervention of levers, &c., in any desired degree, upon valves, stopcocks, stove-registers, air-ventilators, &c.; so as to regulate the temperature of the media in which the said compound bars are placed. Two long rulers, one of steel, and one of hard hammered brass, riveted together, answer very well; the object being not simply to *indicate*, but to *control* or *modify* temperature. The following diagrams will illustrate a few out of the numerous applications of this instrument:

Fig. 955, *a*, *b*, is a single thermostatic bar, consisting of two or more bars or rulers of differently expansible solids (of which, in certain cases, wood may be one): these bars or rulers are firmly riveted or soldered together, face to face. One end of the compound bar is fixed by bolts at *a*, to the interior of the containing cistern, boiler, or apartment, *a l m b*, whereof the temperature has to be regulated, and the other end of the compound bar at *b*, is left free to move down towards *c*, by the flexure which will take place when its temperature is raised.

The end *b*, is connected by a link, *b d*, with a lever *d e*, which is moved by the flexure into the dotted position *b g*, causing the turning-valve, air-ventilator, or register, *o n*, to revolve with a corresponding angular motion, whereby the lever will raise the equipoised slide-damper *k i*, which is suspended by a link from the end *e*, of the lever *e d*, into the position *k h*. Thus a hothouse or a water-bath may have its temperature regulated by the contemporaneous admission of warm, and discharge of cold air, or water.

Fig. 956, *a b c* is a thermostatic hoop, immersed horizontally beneath the surface of the water-bath of a still. The hoop is fixed at *a*, and the two ends *b c*, are connected by two links *b d*, *c d*, with a straight sliding rod *d h*, to which the hoop will give an endwise motion, when its temperature is altered; *e*, is an adjusting screw-nut on the rod *d h*, for setting the lever *f g*, which is fixed on the axis of the turning-valve or cock *f*, at any desired position, so that the valve may be opened or shut at any desired temperature, corresponding to the widening of the points *b*, *c*, and the consentaneous retraction of the point *d*, towards the circumference *a b c* of the hoop. *g h*, is an arc graduated by a thermometer, after the screw-piece *e* has been adjusted. Through a hole at *h*, the guide-rod passes; *i*, is the cold-water cistern; *i f h*, the pipe to admit cold water; *l*, the overflow pipe, at which the excess of hot water runs off.

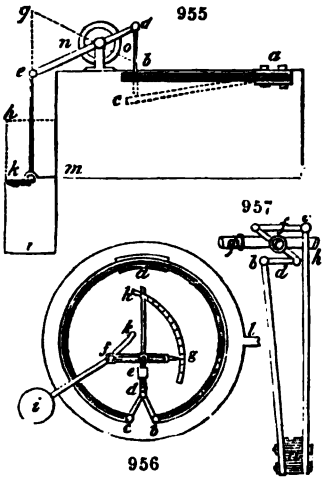


Fig. 957 shows a pair of thermostatic bars, bolted fast together at the ends *a*. The free ends *b*, *c*, are of unequal length, so as to act by the cross links *d*, *f*, on the stop-cock *e*. The links are jointed to the handle of the turning plug of the cock, on opposite sides of its centre; whereby that plug will be turned round in proportion to the widening of the points *b*, *c*. *h g* is the pipe communicating with the stopcock.

Suppose that for certain purposes in pharmacy, dyeing, or any other chemical art, a water-bath is required to be maintained steadily at a temperature of 150°F.: let the combined thermostatic bars, hinged together at *e*, *f*, *fig.* 958, be placed in the bath between the outer and inner vessels *a*, *b*, *c*, *d*, being bolted fast to the inner vessel at *g*; and have their sliding rod *k*, connected by a link with a lever fixed upon the turning plug of the stopcock *i*, which introduces cold water from a cistern *m*, through a pipe *m*, *i*, *n*, into the bottom part of the bath. The length of the link must be so adjusted that the flexure of the bars, when they are at a temperature of 150°, will open the said stopcock, and admit cold water to pass into the bottom of the bath through the pipe *i n*, whereby hot water will be displaced at the top of the bath through an open overflow-pipe at *q*. An oil bath may be regulated on the same plan; the hot oil overflowing from *q*, into a refrigeratory worm, from which it may be restored to the cistern *m*. When a water bath is heated by the distribution of a tortuous steam pipe through it, as *i n o p*, it will be necessary to connect the link of the thermostatic bars with the lever of the turning plug of the steam-cock, or of the throttle valve *i*, in order that the bars, by their flexure, may shut or open the steam passage more or less, according as the temperature of the water in the bath shall tend more or less to deviate from the pitch to which the apparatus has been adjusted. The water of the condensed steam will pass off from the sloping winding-pipe *i n o p*, through the sloping orifice *p*. A saline acid or alkaline bath has a boiling temperature proportional to its degree of concentration, and may therefore have its heat regulated by immersing a thermostat in it and connecting the working part of the instrument with a stopcock *i*, which will admit water to dilute the bath whenever by evaporation it has become concentrated, and has acquired a higher boiling point. The space for the bath, between the outer and inner pans, should communicate by one pipe with the water cistern *m*, and by another pipe with a safety cistern *r*, into which the bath may be allowed to overflow during any sudden excess of ebullition.

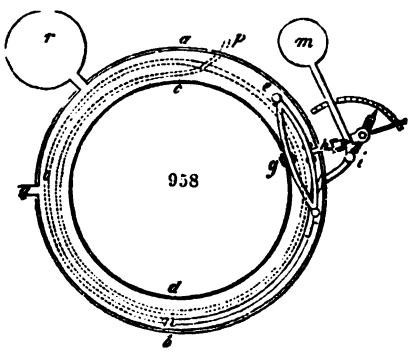


Fig. 961 is a thermostatic apparatus, composed of three pairs of bars *d d d*, which are represented in a state of flexure by heat; but they become nearly straight

and parallel when cold. *a b c* is a guide rod, fixed at one end by an adjusting screw *e*, in the strong frame *f e*, having deep guide grooves at the sides. *f g*, is the working-rod, which moves endways when the bars *d d d*, operate by heat or cold. A square register-plate *h g*, may be affixed to the rod *f g*, so as to be moved backwards and forwards thereby, according to the variations of temperature; or the rod *f g*, may cause the circular turning air-register, *i*, to revolve by rack and wheel work, or by a chain and pulley. The register-plate *h g*, or turning register *i*, is situated at the ceiling or upper part of the chamber, and serves to let out hot-air. *k*, is a pulley, over which a cord runs to raise or lower a hot-air register *l*, which may be situated near the floor of the apartment or hot-house, to admit hot air into the room. *c* is a milled head, for adjusting the thermostat, by means of the screw at *e*, in order that it may regulate the temperature to any degree.

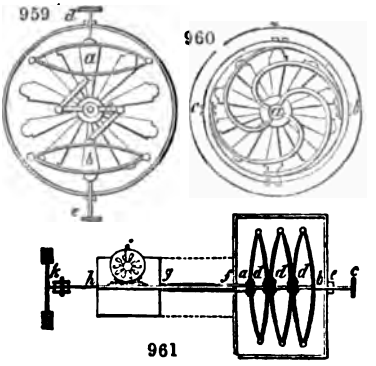


Fig. 962 represents a chimney, furnished with a *pyrostat*, *a b c*, acting by the links *b*, *d*, *e*, *c*, on a damper *f h g*. The more expansible metal is in the present example supposed to be on the outside. The plane of the damper-plate will, in this case, be turned more directly into the passage of the draught through the chimney by increase of temperature.

Fig. 960 represents a circular turning register, such as is used for a stove, or stove-grate, or for ventilating apartments; it is furnished with a series of spiral thermostatic bars, each bar being fixed fast at the circumference of the circle *b*, *c*, of the fixed plate of the air-register; and all the bars act in concert at the centre *a* of the turning part of the register; by their ends being inserted between the teeth of a small pinion, or by being jointed to the central part of the turning plate by small pins.

962

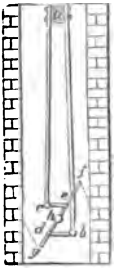


Fig. 959 represents another arrangement of my thermostatic apparatus applied to a circular turning register, like the preceding, for ventilating apartments. Two pairs of compound bars are applied so as to act in concert, by means of the links *a c*, *b c*, on the opposite ends of a short lever which is fixed on the central part of the turning plate of the air-register. The two pairs of compound bars *a b*, are fastened to the circumference of the fixed plate of the turning register, by two sliding rods *a d*, *b e*, which are furnished with adjusting screws. Their motion or flexure is transmitted by the links *a c* and *b c*, to the turning plate, about its centre, for the purpose of shutting or opening the ventilating sectorial apertures, more or less, according to the temperature of the air which surrounds the thermostatic turning register. By adjusting the screws *a d*, and *b c*, the turning register is made to close all its apertures at any desired degree of temperature; but whenever the air is above that temperature, the flexure of the compound bars will open the apertures.

HEAVE, *a miner's term*, expressing the dislocation of a lode. See FAULT.

HEAVY-SPAR, SULPHATE OF BARYTES, or CAWK* (*Spath pesant*, Fr.; *Schwerspath*, Germ.), is an abundant mineral, which accompanies veins of lead, silver, mercury, &c., but is often found, also, in large masses. Its colour is usually white, or flesh coloured. It varies from translucent to opaque. It belongs to the trimetric system, but it occurs in many crystalline forms, of which the cleavage is a right rhomboidal prism. It is met with also of a fibrous, radiated, and granular structure. Its sp. gr. varies from 4·1 to 4·7 H = 2·5 to 3·5. It has a strong lustre, between the fatty and the vitreous, sometimes pearly. It melts at 35° Wedgw. into a white opaque enamel. Its constituents are 65·67 baryta, and 34·33 sulphuric acid; but it is sometimes rendered impure by oxide of iron, silica, carbonate of lime and alumina, and commonly by sulphate of strontian. It is not acted upon by acids; decrepitates before the blowpipe; and is difficultly fusible, or only on the edges. In the inner flame is reduced to a sulphuret, and the globule when moistened smells slightly hepatic. It is decomposed by calcination in contact with charcoal at a white heat, into sulphuret of baryta; from which all the baryta salts may be readily formed. Its chief employment in commerce is for adulterating white lead; a purpose which it

* The term *Cawk* has been applied to the opaque massive variety, of an earthy appearance, and dirty-white colour, which is found in Derbyshire and Staffordshire.

readily serves on account of its density. Its presence here is easily detected by dilute nitric acid, which dissolves the carbonate of lead, and leaves the heavy spar. It is also a useful ingredient in some kinds of pottery, and glass.

In 1856 the following quantities were raised (*Hunt's Mineral Statistics*):—

			Tons.	Cwts.
Alston Moor - - -	Carbonate	- -	443	16
Northumberland, *Fallowfield*	do	- -	1045	18
Derbyshire - - -	Sulphate*	- -	8000	0
Lauderdale and Skipton -	do	- -	1000	0
Bantry, Ireland - -	do	- -	700	0
Kirkcudbright - -	do	- -	70	0
Isle of Arran - -	do	- -	550	0

HECKLE (*Seran*, Fr.; *Hechel*, Germ.) is an implement for dissevering the filaments of flax, and laying them in parallel stricks or tresses. See FLAX.

HELIOGRAPHY was the name given by M. Niepce to his process for obtaining, through the agency of the solar rays upon plates of metal or glass covered with resins, the impression of external objects. The process has been employed of late years in preparing lithographic stones, and steel or copper plates, for receiving photographic impressions, which might be subsequently printed from. The name heliography is a far more appropriate one than photography; but the latter has become too permanently fixed in our language to leave any hope of our returning to the former. See PHOTOGRAPHY.

HELIOTROPE is a variety of jasper, mixed with chlorite, green earth, and diallage; occasionally marked with blood red points; whence its vulgar name of *blood-stone*.

HEMATINE is the name given by its discoverer Chevreul to a crystalline substance, of a pale pink colour, and brilliant lustre when viewed in a lens, which he extracted from logwood, the *Hæmatoxylon Campechianum* of botanists. It is, in fact, the characteristic principle of this dye wood. To procure hematine, digest during a few hours ground logwood in water heated to a temperature of about 130° Fahr.; filter the liquor, evaporate it to dryness by a steam bath, and put the extract in alcohol of 0·835 for a day. Then filter anew, and after having inspissated the alcoholic solution by evaporation, pour into it a little water, evaporate gently again, and then leave it to itself in a cool place. In this way numerous crystals of hematine will be obtained, which may be purified by washing with alcohol and drying.

When subjected to dry distillation in a retort, hematine affords all the usual products of vegetable bodies, along with a little ammonia; which proves the presence of azote. Boiling water dissolves it abundantly, and assumes an orange-red colour, which passes into yellow by cooling, but becomes red again with heat. Sulphurous acid destroys the colour of solution of hematine. Potash and ammonia convert into a dark purple-red tint the pale solution of hematine; when these alkalies are added in large quantity, they make the colour violet blue, then brown-red, and lastly brown-yellow. By this time the hematine has become decomposed, and cannot be restored to its pristine state by neutralising the alkalies with acids.

The waters of baryta, strontia, and lime exercise an analogous power of decomposition; but they eventually precipitate the changed colouring matter.

A red solution of hematine subjected to a current of sulphuretted hydrogen becomes yellow; but it resumes its original hue when the sulphuretted hydrogen is removed by a little potash.

The protoxide of lead, the protoxide of tin, the hydrate of peroxide of iron, the hydrate of oxides of copper and nickel, oxide of bismuth, combine with hematine, and colour it blue with more or less of a violet cast.

Hematine precipitates glue from its solution in reddish flocks. This substance has not hitherto been employed in its pure state; but as it constitutes the active principle of logwood, it enters as an ingredient into all the colours made with that dye stuff.

These colours are principally violet and black. Chevruel has proposed hematine as an excellent test of acidity.

HEMATITE (*Fer Oligiste*, Fr.; *Rotheisenstein*, Germ.) is a native reddish-brown peroxide of iron. This term was applied to this ore of iron by the ancients, on account of the red colour of its powder, from ἁεμα blood.

This species includes *specular iron* and the *old red iron ore* (see IRON, SPECULAR; MICACEOUS). "The varieties of a sub-metallic or non-metallic lustre were included under the names of *red hematite, fibrous red iron*, or of soft and earthy *red ochre*, and when consisting of slightly coherent scales, *scaly red iron* or *red iron froth*" (*Dana*). Dana also includes, most injudiciously as it appears, *reddle* or *red chalk*, and *jaspery clay iron ore*, with some others, among the hematites.

* This is manufactured at Liverpool, Wigan, and Welshpool.

The hematite proper occurs in a remarkable manner at Whitehaven and at Ulverstone. The following analysis of the Whitehaven ore of Cleator Moor by Mr. A. Dick, shows its peculiar character: —

Peroxide of iron	95·16
Protoxide of manganese	0·24
Lime	0·07
Phosphoric acid	trace
Sulphuric acid	trace
Bisulphide of iron	trace
Insoluble residue	5·68
	101·15
Iron, total amount	66·60

The following analysis of the Ulverstone ore is by the same chemist: —

Gillbrow Ore.

Peroxide of iron	86·50
Protoxide of manganese	0·21
Lime	2·77
Magnesia	1·46
Carbonic acid	2·96
Phosphoric acid	trace
Sulphuric acid	0·11
Insoluble residue	6·55
	100·56
Iron, total amount	60·55

Another ore, that of Lindale Moor, near Ulverstone, was analysed by Mr. J. Spiller.

Peroxide of iron	94·23
Protoxide of manganese	0·23
Alumina	0·51
Lime	0·05
Magnesia	trace
Phosphoric acid	minute trace
Sulphuric acid	0·09
Bisulphide of iron	0·03
Water, hygroscopic	0·39
„ combined	0·17
Insoluble residue	5·18
	100·88
Iron, total amount	65·98

In 1857 Whitehaven district produced of hematite, 323,812 tons; and in 1858, 348,638 tons; and the Lancashire or Ulverstone district, 592,390 tons in 1857, and 438,546 in 1858.

A small quantity of the Ulverstone ore is smelted with charcoal at some furnaces in the district, and the following quantities of this ore were used at the furnaces near Whitehaven:—

Cleator Moor furnaces	47,311
Harrington „	3,000
Leaton „	6,200
	56,511

All the remainder was sent into the other great iron-making districts for mixing with the argillaceous carbonates, and other ores of iron. See IRON.

HEMATOSIN. The red colouring matter of blood, which is sold in a dry state for making Prussian blue.

HEMLOCK SPRUCE. The *Abies Canadensis*, the wood of which has been used for railway sleepers, and is employed for laths.

HEMP. (*Chanvre*, Fr.; *Hanf*, Germ.) A plant (*Cannabis sativa*), a native of India, but has been long introduced into Europe, and cultivated extensively in Italy, and in Russia and Poland; a small quantity has been cultivated in Suffolk, in Lincolnshire, and in Ireland.

Hemp is assorted, into *clean hemp*, *out-shot hemp*, *half clean hemp*, and *hemp codilla*. According to M'Culloch, a bundle of clean hemp from Russia weighs 55 to 65 poods; of out shot, from 48 to 55 poods; of half clean, 40 to 45 poods; the pood being equal to 36 lbs. avoirdupoise

Manilla Hemp is the produce of the wild banana, *Musa textilis*. "It is known," says Mr. Crauford in his history of the Eastern Archipelago, "to our traders and navigators under the name of Manilla rope, and is equally applicable to cables and to standing or running rigging."

SUNN and JUTE are two varieties of hemp. Hemp is used in the manufacture of *huckaback* for towels and common tablecloths, and of the low priced cloth worn by agricultural labourers. The largest consumption of this material is in the manufacture of sail cloth and cordage.

Our *imports* of hemp were as follows in 1857:—

	Hemp dressed.	Hemp undressed.	Codilla of hemp.	Jute.
	Cwts.	Cwts.	Cwts.	Cwts.
Russia	29,747	545,266	5,684	
Prussia	-	10,546		
Austrian Italy	4,043	22,005	2,771	
Philippine Islands	-	55,861		
British East Indies	1,874	45,326	-	536,438
United States	-	42,254	-	80,215
Hanse Towns	-	-	2,045	
Holland	-	-	2,092	
Spain	-	-	1,681	
Other parts	1,624	18,680	701	2,180
	37,288	739,938	14,975	618,833

HEMP SEED. (*Chenevis*, Fr.; *Hanfsaat* Germ.) The seed of the hemp; it is used for crushing, for its oil, or as food for birds.

In 1857 we *imported* 4,727 quarters of hemp seed, the computed real value of which was 10,636*l*.

HENBANE. The *Hyosciamus niger*. Henbane is a plant used in medicine, from which modern chemistry has extracted a new crystalline vegetable principle called *hyosciamine*, which is very poisonous, and when applied in solution to the eye, determines a remarkable dilatation of the pupil; as *belladonna* also does.

HENNA. The herb used for dyeing the nails in the East. See ALKENNA.

HEPAR, which signifies liver in Latin, was a name given by the older chemists to some of the compounds of sulphur.

HEPATIC AIR. Sulphuretted hydrogen gas.

HERMETICAL SEAL, is an expression derived from Hermes, who was said to be the parent of Egyptian chemistry. It is used to designate the perfect closure of a hollow vessel, by the cementing or melting of the lips of its orifice; as in the case of a glass thermometer, or matrass.

HERNANDIA OVIGERA. Hernant seeds, some of which are imported from India for tanning.

HESSONITE, or *Essonite*. The name given by Hauy to cinnamon stone.

HICKORY. The *Juglans alba*; white walnut, a native of America. It is used for making handspikes, and other elastic tools.

The bark has been recommended by Dr. Bancroft as a yellow dye.

HIDE. (*Peau*, Fr.; *Haut*, Germ.) The strong skin of an ox, horse, or other large animal. The lists of *imports* below will show to what an extent a trade in the skins of animals is carried on with this country. We receive hides largely from Russia and the north of Europe. From America there are also large quantities brought to this country.

The following table shows the number of salted and dry hides which were exported from Bahia in the five years ending September, 1855.

	Number of hides.	Price salted.	Price dry.
		per hide.	per hide.
1850—51	90,040	3½*d*.	4*d*.
1851—52	93,484	3*d*.	3½*d*.
1852—53	108,783	3½*d*.	4½*d*.
1853—54	128,675	4¾*d*.	5½*d*.
1854—55	134,231	5*d*.	6*d*.

From the Dominican Republic (Puerto Plata) the number of hides exported was in 1854, 15,514; and in 1855, 10,836; they went chiefly to the United States.

From Equator (Guayaquil), during 1855, there were exported principally for the Lima market, 26,246, valued at 10,482*l.* 16*s.* 8*d.*

From Guatemala, 20,991 hides were exported in 1855.

From Salvador, 24,255, valued at 27,347 dollars, in 1855.

HIPPOCASTANUM. The common horse-chestnut.

HIPPOPOTAMUS TEETH. See IVORY.

HOG'S LARD, or *Axungi;* the latter name derived from the use to which it was put by the ancients, *i. e.* to grease the axle of a wheel. It is obtained from all the hog tribe (*Sus scrofa*). Hog's lard is largely used in the manufacture of ointments, pomatum, &c. Its proximate analysis gives, according to Braconnot:—

Stearine and margarine, 38; elaine, 62.

The stearine is separated and used in the manufacture of candles, and the elaine sold under the name of Lard Oil. The ultimate analysis of lard gives—

Carbon, 79·2; hydrogen, 11·1; oxygen, 9·7.

HOLLAND. A linen fabric, which is sold when unbleached as *brown holland*, and which is used when bleached for finer purposes. See LINEN.

HOLLANDS. A grain spirit manufactured in Holland.

HOLLY. (*Le Houx*, Fr.; *Stechpalme*, Germ.) The *Ilex aquifolium* of Linnæus, a British plant. Its leaves yield a yellow colouring matter similar to that obtained from buckwheat. The wood is as white as ivory, very hard and fine grained, and susceptible of a high polish; it is employed for many purposes.

HOMOLOGOUS. A term used in organic chemistry to denote that substances differ by the constant increment C^2H^2. Thus, in the great series of acids commencing with the formic and extending up to the fatty acids, each *homologue* contains C^2H^2 more than the one before, and C^2H^2 less than the one following, thus:—

Formic acid	$C^2H^2O^4$	Propionic acid	$C^6H^6O^4$
Acetic acid	$C^4H^4O^4$	Butyric acid	$C^8H^8O^4$ &c.—C. G. W.

HONDURAS MAHOGANY. — See MAHOGANY.

HONES AND HONE SLATES. These are slaty stones which are used in straight pieces for sharpening tools after they have been ground on revolving grindstones. The more important varieties are the following: —

The Norway Ragstone which is the coarsest variety of the hone slates, is imported in large quantities from Norway. In Charnwood Forest, near Mount Sorrel, in Leicestershire, particularly from the Whittle Hill quarry, are obtained the *Charnley Forest Stone*, said to be one of the best substitutes for the Turkey oilstone, and it is much in request by joiners and others. *Ayr stone*, *Snake stone*, and *Scotch stone*, are used especially for polishing copper plates. The *Welsh oilstone* is almost in equal repute with the Charnley Forest stone; it is obtained from the vicinity of Llyn Idwall, near Snowdon, and hence it is sometimes called *Idwall stone*. From Snowdon is also obtained the *cutler's green stone*. The *Devonshire oilstones*, obtained near Tavistock, which were introduced by Mr. John Taylor, are of excellent quality, but the supply of them being irregular they have fallen into disuse.

The *German razor hone* has been long celebrated. It is obtained from the slate mountains in the neighbourhood of Ratisbon, where it occurs in the form of a yellow vein running through the blue slate, varying in thickness from 1 to 18 inches. When quarried it is sawn into thin slabs, and these are generally cemented to slices of slate which serve as a support. Sometimes, however, the yellow and the blue slate are cut out naturally combined. There are several other hone stones, which, however, require no particular notice.

The *Turkey oilstone* is said to surpass in its way every other known substance, and it possesses in an eminent degree the property of abrading the hardest steel; it is, at the same time, of so compact and close a nature as to resist the pressure necessary for sharpening a graver, or any instrument of that description. There are white and black varieties of the Turkey oilstone, the black being the hardest, and it is imported in somewhat larger pieces than the white; they are found in the interior of Asia Minor and are brought down to Smyrna for sale.

HONEY (*Mel*, Fr.; *Honig*, Germ.) is a sweet viscid liquor, secreted in the nectaries of flowers, collected by the working bees, and deposited by them in the waxen cells of their combs. Virgin honey is that which is collected from a hive, the bees of which have never swarmed, the common honey is obtained from the older hives. The former, which is considered the best, is whitish or pale yellow, of a granular texture, a fragrant smell, and a sweet slightly pungent taste; the latter is darker coloured, thicker, and

not so agreeable either in taste or smell. Honey would seem to be simply collected by the bees, for it consists of merely the vegetable products; such as the sugars of grape, gum, and manna; along with mucilage, extractive matter, a little wax, and acid.

Narbonne honey, the flavour of which is so much admired, owes its peculiarity to the flowers on which the bees feed.

Trebizond honey has been long celebrated for its intoxicating qualities. The description given in Xenophon's *Retreat of the Ten Thousand* is well known. Many examples of poisonous honey are on record.

HONEY COMB. The waxen cells of the bee. See WAX.

HONEY-STONE (*Mellite*, Fr.; *Honigstein*, Germ.) is a mineral of a yellowish or reddish colour, and a resinous aspect, crystallising in octahedrons with a square base; specific gravity 1·58. It is harder than gypsum, but not so hard as calc-spar; it is deeply scratched by a steel point; very brittle; affords water by calcination; blackens, then burns at the flame of the blowpipe, and leaves a white residuum which becomes blue when it is calcined, after having been moistened with a drop of nitrate of cobalt. It is a mellate of alumina, and consists of:

	Klaproth.	Wöhler.
Mellitic acid	46	44·4
Alumina	16	14·5
Water	81	41·1
	100	100·0

The honey-stone, like amber, belongs to the geological formation of lignite. It has been hitherto found only at Artern in Thuringia; at Luschitz, near Bilin in Bohemia; and near Walchow in Moravia.

HOP (*Houblon*, Fr.; *Hopfen*, Germ.) is the name of a well-known plant of the natural family of Urticeæ, and of the *Diœcia pentandria* of Linnæus. The female flowers, placed upon different plants from the male, grow in ovoid cones formed of oval leafy scales, concave, imbricated, containing each at the base an ovary furnished with two tubular open styles, and sharp pointed stigmata. The fruit of the hop is a small rounded seed, slightly compressed, brownish coloured, enveloped in a scaly calyx, thin, but solid, which contains, spread at its base, a granular yellow substance, appearing to the eye like a fine dust, but in the microscope they seem to be round, yellow, transparent, grains; deeper coloured, the older the fruit. This secretion which constitutes the useful portion of the hop, has been examined in succession by Ives, Planche, Payen, and Chevallier. A pretty full account of the results of their researches in treating of the hop is given in the article BEER.

Number of Acres under the Cultivation of Hops in England.

1807	38,218	1813	39,521	1819	51,014	1825	46,718	1831	47,129	1837	56,333
1808	38,486	1814	40,571	1820	50,148	1826	50,471	1832	47,101	1838	53,045
1809	38,357	1815	42,150	1821	45,662	1827	49,485	1833	49,187	1839	52,305
1810	38,265	1816	44,219	1822	43,766	1828	48,365	1834	51,273	1840	44,805
1811	38,401	1817	46,493	1823	41,458	1829	46,135	1835	53,816	1841	45,769
1812	38,700	1818	48,593	1824	43,449	1830	46,726	1836	55,422		

Hop Duties of particular Districts.

	1841.	1842.	1844.	1845.
	£ s. d.	£ s. d.	£ s. d.	£ s. d.
Rochester	51,490 3 8	58,812 4 7	62,407 3 2	51,056 5 0
Canterbury	33,960 14 10	31,019 13 5	21,158 15 8	36,591 6 3
Sussex	38,086 13 10	43,561 10 0	27,303 2 1	54,304 5 11
Worcester	12,076 19 8	19,825 2 11	17,409 6 4	9,091 1 9
Farnham	7,702 10 2	11,678 18 4	10,080 0 4	5,425 5 11
Essex	977 3 0	2,050 19 11	804 6 2	1,534 17 4
North Clays	1,189 7 10	1,724 2 7	770 7 0	
Sundries	705 8 7	263 14 3	389 16 5	
	146,159 1 7	169,776 6 0	140,322 17 2	158,003 12 2

Parliamentary Return relative to the Hop produce of the last four years.

Collecting Districts.	Number of Statute Acres under Cultivation.				Average Amount of Duty per Acre.								Quantity of Hops charged with Duty.			
	1855.	1856.	1857.	1858.	1855.			1856.			1857.			1858.			1855.	1856.	1857.	1858.
					£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	lbs.	lbs.	lbs.	lbs.
Canterbury -	12,694¼	11,665	10,850¾	9,552¼	12	13	5	10	9	0	5	19	3	10	4	0	18,385,809	13,932,542	7,397,942	11,136,044
Essex - -	182	178	141	152½	9	11	11	4	14	7	11	11	0	6	15	4	199,642	96,204	186,144	117,962
Hants - -	2,371	2,286¾	2,064¼	2,044	13	10	11	7	11	11	11	1	5	8	8	0	3,671,414	1,985,491	2,612,572	1,971,091
Hereford -	4,745	4,602	4,213¾	4,089	8	10	9	1	3	10	10	0	1	5	5	7	4,630,524	626,964	4,818,253	2,467,302
Isle of Wight	1,496	1,523	1,441	1,343½	13	17	2	7	10	1	11	8	2	8	1	8	2,369,956	1,306,843	1,878,821	1,241,591
Lincoln - -	27¼	27¼	26½	22½	7	1	0	5	19	7	8	0	8	6	0	3	21,974	18,626	24,339	15,468
Nottingham -	20	9¼	7	7	6	4	9	1	16	5	11	9	0	5	10	6	14,261	1,927	9,161	4,422
Reading -	9½	9½	14	12	12	15	4	5	3	6	8	8	5	2	16	7	13,862	5,619	13,478	3,885
Rochester -	20,397	19,583¼	18,452	17,974¾	13	0	1	9	17	1	9	6	6	9	18	7	30,317,459	22,063,031	19,671,056	20,405,455
Sheffield -	159½	165¼	152½	128½	6	7	4	3	16	2	8	14	2	3	15	2	116,077	71,936	151,827	55,249
Stourbridge -	1,460	1,396½	1,327	1,319½	7	17	5	1	19	3	8	10	8	4	15	1	1,313,745	313,696	1,294,580	716,946
Suffolk - -	142½	140	137¾	134½	10	8	6	6	9	10	11	9	2	8	1	0	169,811	103,856	180,424	123,763
Surrey - -	131¾	113½	53¾	50	12	5	3	8	17	7	10	16	3	8	10	11	184,688	115,172	66,423	48,854
Sussex - -	12,586	11,555¼	10,891¼	9,640¾	14	2	8	11	7	1	6	7	7	12	16	7	20,331,789	14,996,915	7,941,120	14,136,358
Wales, Middle	20	20	22	25	7	15	3	0	14	2	8	17	7	3	19	6	17,752	1,621	22,327	11,359
Worcester -	1,274	1,210½	1,141¾	1,071½	9	17	1	1	11	9	10	16	10	5	7	9	1,435,379	219,898	1,415,073	660,245
Other Districts	40¾	41¾	38½	34¼	-	-		-	-		-	-		-	-		27,163	8,586	33,021	9,106
	57,757¼	54,527	50,974¾	47,601½	12	12	1	8	19	3	8	3	9	9	15	3	83,221,304	55,868,927	47,717,561	53,125,100

Annual Amount of Hop Duty.

Years.	Amount.	Years.	Amount.	Years.	Amount.	Years.	Amount.	Years.	Amount.	Years.	Amount.
	£		£		£		£		£		£
1711	43,437	1735	42,745	1759	42,115	1783	75,716	1807	100,071	1830	88 047
1712	30,278	1736	46,482	1760	117,992	1784	94,259	1808	251,089	1831	174,564
1713	23,018	1737	56,492	1761	79,776	1785	112,684	1809	63,452	1832	139,014
1714	14,457	1738	86,575	1762	79,295	1786	95,973	1810	73,514	1833	156 905
1715	44,975	1739	70,742	1763	88,315	1787	42,227	1811	157,025	1834	189.713
1716	20,354	1740	37,875	1764	17,178	1788	143,168	1812	30,643	1835	235 307
1717	54,669	1741	65,222	1765	73,778	1789	104,063	1813	131,482	1836	200,332
1718	15,005	1742	45,550	1766	116,445	1790	106,841	1814	140,202	1837	178,578
1719	90,317	1743	61,072	1767	25,997	1791	90,050	1815	123,878	1838	171.556
1720	38,169	1744	46,708	1768	114,002	1792	162,112	1816	46,302	1839	205,537
1721	61,362	1745	34,636	1769	16,201	1793	22,619	1817	66,522	1840	34,091
1722	49,443	1746	91,879	1770	101,131	1794	203,063	1818	199,465	1841	146.156
1723	80,279	1747	62,993	1771	33,143	1795	82,342	1819	242,476	1842	179.776
1724	61,371	1748	87,155	1772	102,650	1796	75,223	1820	138,330	1843	133 431
1725	66,526	1749	36,805	1773	45,847	1797	157,458	1821	154,609	1844	140,322
1726	80,031	1750	72,138	1774	138,887	1798	56,032	1822	203,734	1845	158,0??
1727	69,409	1751	73,954	1775	41,597	1799	73,279	1823	26,058	1846	242 929
1728	41,494	1752	82,163	1776	125,691	1800	72,928	1824	148,832	1847	215,605
1729	48,441	1753	91,214	1777	43,581	1801	241,227	1825	24,317	1848	212.416
1730	44,419	1754	102,012	1778	159,891	1802	15,463	1826	269,331	1849	79,791
1731	22,600	1755	82,157	1779	55,800	1803	199,305	1827	140,844	1850	233.392
1732	35,135	1756	48,106	1780	122,724	1804	177,617	1828	172,027	1851	130.056
1733	70,215	1757	69,713	1781	120,218	1805	32,904	1829	38,398	1852	240,000
1734	37,716	1758	72,896	1782	14,895	1806	153,102				

Pounds weight of hops which paid duty, which were exported on drawbacks or free of duty, and retained for home consumption.

Years.	Charged with Duty.	Exported on Drawback or free of Duty.	Retained for Home Consumption.
	lbs.	lbs.	lbs.
1842 - - - -	35,432,142	662,832	34,769,310
1843 - - - -	27,862,725	292,709	27,570,016
1844 - - - -	29,285,004	153,849	29,131,245
1845 - - - -	32,974,749	151,211	32,823,538
1846 - - - -	50,704,025	448,497	50,255,528
1847 - - - -	45,134,365	457,061	44,677,304
1848 - - - -	44,343,985	357,029	43,986,956
1849 - - - -	16,650,915	274,811	16,376,104
1850 - - - -	48,537,669	270,511	48,267,158
1851 - - - -	27,042,996	904,090	26,138,906
1852 - - - -	51,102,494	955,855	50,146,639
1853 - - - -	31,751,693	802,103	30,949,590
1854 - - - -	9,877,126	585,168	9,291,958
1855 - - - -	83,221,004	852.856	82.368,448
1856 - - - -	55,868,624	1,565,249	54,303,375
1857 - - - -	47,717,561	1,450,104	46,267,457
1858 - - - -	53,125,100	4,177,250	48,947,850

HORDEINE is the name given by Proust to the peculiar starchy matter of barley. It seems to be a mixture of the starch, lignine, and husks, which constitute barley meal. See BEER.

HORN (Eng. and Germ ; *Bois, Corne*, Fr.), particularly of oxen, cows, goats, and sheep, is a substance soft, tough, semi-transparent, and susceptible of being cut and pressed into a variety of forms; it is this property that distinguishes it from bone. Turtle or tortoise shell seems to be of a nature similar to horn, but instead of being of a uniform colour, it is variegated with spots. See TORTOISE SHELL.

Mr. Aikin (*Trans. Soc. of Arts*) remarks, "In the English language we have only one word to express two quite different substances; namely, the branched bony horns of the stag genus, and the simple laminated horns of the ox genus, and other kindred genera. The bony horns are called in the French *bois*, from their likeness to the branch of a tree : they are annually renewed. The other horn to which the French appropriate the term *corne*, is found on the ox, the antelope, the goat, and sheep kinds."

The valuable properties of horn render it susceptible of being employed in a variety of works fit for the turner, snuff-box, and comb maker. The means of softening the horn need not be described, as it is well known to be by heat ; but those of cutting, polishing, and soldering it, so as to make plates of large dimensions, suitable to form a variety of articles, may be detailed. The kind of horn to be preferred is

that of goats and sheep, from its being whiter and more transparent than the horn of any other animals. When horn is wanted in sheets or plates, it must be steeped in water, in order to separate the pith from the kernel, for about fifteen days in summer, and a month in winter; and after it is soaked, it must be taken out by one end, well shaken and rubbed in order to get off the pith; after which it must be put for half an hour into boiling water, then taken out, and the surface sawed even lengthways; it must again be put into the boiling water to soften it, so as to render it capable of separating; then, with the help of a small iron chisel, it can be divided into sheets or leaves. The thick pieces will form three leaves, those which are thin will form only two, whilst young horn, which is only one quarter of an inch thick, will form only one. These plates or leaves must again be put into boiling water, and when they are sufficiently soft, they must be scraped with a sharp cutting instrument, to render those parts that are thick even and uniform; they must be put once more into the boiling water, and finally carried to the press.

At the bottom of the press employed, there must be a strong block, in which is formed a cavity, of nine inches square, and of a proportionate depth; the sheets of horn are to be laid within this cavity, in the following manner: at the bottom, first a sheet of hot iron, upon this a sheet of horn, next again a sheet of hot iron, and so on, taking care to place at the top a plate of iron even with the last. The press must then be screwed down tight.

There is a more expeditious process, at least in part, for reducing the horn into sheets, when it is wanted very even. After having sawed it with a very fine and sharp saw, the pieces must be put into a copper made on purpose, and there boiled until sufficiently soft, so as to be able to be split with pincers; the sheets of horn must then be put in the press where they are to be placed in a strong vice, the chaps of which are of iron and larger than the sheets of horn, and the vice must be screwed as quick and tight as possible; let them cool in the press or vice, or it is as well to plunge the whole into cold water. The last mode is preferable, because the horn does not shrink in cooling. Now draw out the leaves of horn, and introduce other horn to undergo the same process. The horn so enlarged in pressing, is to be submitted to the action of the saw, which ought to be set in an iron frame, if the horn is wanted to be cut with advantage, in sheets of any desired thickness, which cannot be done without adopting this mode. The thin sheets thus produced must be kept constantly very warm between plates of hot iron to preserve their softness; every leaf being loaded with a weight heavy enough to prevent its warping. To join the edges of these pieces of horn together, it is necessary to provide strong iron moulds suited to the shape of the article wanted, and to place the pieces in contact with copper-plates or with polished metal surfaces against them; when this is done, the whole is to be put into a vice and screwed up tight, then plunged into boiling water, and after some time it is to be removed from thence and immersed in cold water. The edges of the horn will be thus made to cement together and become perfectly united.

To complete the polish of the horn, the surface must be rubbed with the subnitrate of bismuth by the palm of the hand. The process is short, and has this advantage, that it makes the horn dry promptly.

When it is wished to spot the horn in imitation of tortoise shell, metallic solutions must be employed as follows: — To spot it red, a solution of gold in aqua regia must be employed; to spot it black, a solution of silver in nitric acid must be used; and for brown, a hot solution of mercury in nitric acid. The right side of the horn must be impregnated with these solutions, and they will assume the colours intended. The brown spots can be produced on the horn by means of a paste made of red lead, with a solution of potash, which must be put in patches on the horn, and subjected some time to the action of heat. The deepness of the brown shades depends upon the quantity of potash used in the paste, and the length of time the mixture lies on the horn. A decoction of Brazil wood, or a solution of indigo, in sulphuric acid, or a decoction of saffron and Barbary wood may also be used. After having employed these materials, the horn may be left for half a day in a strong solution of vinegar and alum.

In France, Holland, and Austria, the comb-maker and horn-turners use the clippings of horn—which are of a whitish yellow—and tortoise-shell skins, out of which they make snuff-boxes, powder-horns, and many curious and handsome things. They first soften the horn and shell in boiling water, so as to be able to submit them to the press in iron moulds, and by means of heat they form them into one mass. The degree of heat necessary to join the horn clippings must be stronger than that for shell skins, and it can only be found out by experience. The heat must not, however, be too great, for fear of scorching the horn or shell. Considerable care is required in these operations, not to touch the horn with the fingers, or with any greasy body, because the grease will prevent the perfect joining. Wooden instruments should be used to move them, while they are at the fire, and for carrying them to the moulds.

In making a ring of horn for bell-pulls, &c., the required piece is to be first cut out

in the flat of its proper dimensions, and nearly in the shape of a horse-shoe; it is then pressed in a pair of dies to give its surface the desired pattern; but previous to the pressure, both the piece of horn and the dies are to be heated; the piece of horn is to be introduced between the dies, squeezed in a vice, and when cold, the impression or pattern will be fixed upon the horn. One particular condition, however, is to be observed in the construction of the dies, for forming a ring. They are to be so made that the open ends of the horse-shoe piece of horn, after being pressed, shall have at one end a nib, and at the other a recess of a dovetailed form, corresponding to each other; and the second operation in forming this ring of horn is to heat it, and place it in another pair of dies, which shall bring its open ends together, and cause the dovetailed joints to be locked fast into each other, which completes the ring, and leaves no appearance of the junction.

In forming the handles of table knives and forks, or other things which require to be made of two pieces, each of the two pieces or sides of the handle is formed in a separate pair of dies; the one piece is made with a counter-sunk groove along each side, and the other piece with corresponding leaves or projecting edges. When these two pieces are formed, by first being cut out of the flat horn, then pressed in the dies in a heated state, for the purpose of giving the pattern, the two pieces are again heated and put together, the leaves or edges of the one piece dropping into the counter-sunk grooves of the other piece, and being introduced between another pair of heated dies, the joints are pressed together and the two pieces formed into one handle.

In making the knobs for drawers which have metal stems or pins to fasten them into the furniture, the face of the knob is to be first made in a die, as above described, and then the back part of the knob with a hole in it; a metal disc plate of iron is next provided, in which the metal stem or screw pin is fixed, and the stem being passed through the aperture in the back piece, and the two, that is, the back and front pieces of horn put together, they are then heated and pressed in dies as above described; the edge of the back piece falling into the counter-sunk groove of the front piece, while by the heat they are perfectly cemented together.

Mr. J. James has contrived a method of opening up the horns of cattle, by which he avoids the risk of scorching or frizzling, which is apt to happen in heating them over an open fire. He takes a solid block of iron pierced with a conical hole, which is fitted with a conical iron plug, heats them in a stove to the temperature of melting lead, and having previously cut up the horn lengthwise on one side with a saw, he inserts its narrow end into the hole, and drives the plug into it with a mallet. By the heat of the irons, the horn gets so softened in the course of about a minute, as to bear flatting out in the usual way.

Importation of Horns, 1857.

Horns and Tips and pieces thereof.	Quantity.	Value.
Hanse towns	tons 237	£21,626
United States	791	29,860
Brazil	243	10,327
Uruguay	234	9,945
Buenos Ayres	289	12,283
British possessions in South Africa	155	5,913
British East Indies	1,592	48,039
Australia	202	5,086
Other parts	195	11,154
	3,938	£154,233

Exportation of Horns, 1857.

	Quantity.	Value.
Horns, tips, and pieces of Horn	cwt. 1327	£51,986

HORNBEAM. The *Carpinus betulus*, sometimes called the yoke-elm. It is a stringy and tough wood which grows in some parts of Europe, and which is imported from America. It is used by millwrights for the cogs of wheels, also for skittles, and for mallets.

HORN SILVER, or LUNA CORNEA. Fused chloride of silver. Both these names were given by the alchemists to this preparation. It is found native. See SILVER, ORES OF.

HORNSTONE. A variety of quartz, resembling flint, but more brittle, and, breaking with a more splintery fracture. It sometimes occurs imbedded in limestone. See CHERT.

HORSE CHESTNUT. (*Marronnier D'Inde*, Fr.; *Gemeine Rosskastanie*, Germ.) The wood of this well known tree is used by the Tunbridge turner. It is only employed for some large varnished works.

HORSE POWER, in steam engines, is estimated by Mr. Watt at 32,000 pounds avoirdupois lifted one foot high per minute, for one horse. M. D'Aubuisson, from an examination of the work done by horses in the whims, or gigs (*machines à molottes*) for raising ore from the mines at Freyberg, the horses being of average size and strength, has concluded that the useful effect of a horse yoked during eight hours, by two relays of four hours each, in a manége or mill course, may be estimated at 40 kilogrammes raised 1 mèter per second; which is nearly 16,440 pounds raised one foot per minute; being very nearly one half of Mr. Watt's liberal estimates for the horse power of his steam engines.

Frederick William Simms, M. Inst. C. E., adopted some peculiar conditions of work on which he was engaged to determine the value of *horse* power. He had to make a tunnel for the South Eastern Railway. This tunnel was driven in the middle bed of the lower green-sand, between which and the surface of the ground is interposed only the upper bed of the same stratum; but in sinking the eleven shafts for the work, it was found that at the level of the top of the tunnel, the ground assumed the character of a quicksand, saturated with water, in such quantity that it could not be reduced by manual labour. Under these circumstances horse gins were erected for drawing the water by barrels, containing one hundred gallons each, weighing when full about 1310 lbs.

The engineer's intention was, to drive simultaneously from these shafts, in the direction of the tunnel, an adit or heading to carry off the water; but the earth, which was sand mixed with fine particles of blue clay, was so filled with water as to become a mass of semifluid mud; great exertions were therefore necessary to overcome the water, without erecting pumps. At first this was accomplished by making each horse work for 12 hours and then for 8 hours per day, allowing one hour for food and rest: as the water increased it became necessary to work night and day, and the time of each horse's working was reduced generally to 6 hours, and sometimes to 3 hours. As all the horses were hired at the rate of seven shillings per day, the engineer, who had the direction of the works, ordered a daily register to be kept of the actual work done by each horse, for the double purpose of ascertaining whether they all performed their duty, and also hoping to collect a body of facts relative to horse power which might be useful hereafter.

Mr. Simms gives as a proposition, "that the proper estimate of horse power would be that which measures the weight that a horse would draw up out of a well; the animal acting by a horizontal line of traction turned into the vertical direction by a simple pulley, whose friction should be reduced as much as possible." He states that the manner in which the work was performed, necessarily approached very nearly to these conditions; and after giving the principal dimensions of the horse gins, he analyses each set of experiments, and by taking the mean of those, against which no objections could be urged, he arrives at the following results:—

The power of a horse for	8 hours	=	23,412 lbs. raised	1 foot high in one minute.
do.	do.	6	= 24,360	do.
do.	do.	4½	= 27,056	do.
do.	do.	3	= 32,943	do.

Of these results, he thinks the experiments for 6 hours and for 3 hours alone should be adopted as practical guides, all the others being in some degree objectionable.

As a means of comparison, the following table of estimates of horse power is given:—

Name.	Pounds raised 1 foot high in a minute.	Hours of work.	Authority.
Boulton and Watt - -	32,000	8	Robinson's Mech. Phil., ii. 145.
Tredgold - - -	27,500	8	Tredgold on Railroads, p. 69.
Desaguliers - - -	44,000	8	Dr. Gregory's Mathematics for Practical Men, p. 183.
Ditto - - - -	27,500	Not stated	
Saussure - - -	34,020	8	
More, for Society of Arts	21,120	Not stated	
Smeaton - - - -	22,000	Not stated	

These are much higher results than the average of his experiments, and would more nearly accord with the extremes obtained by him; but under such excessive fatigue, the horses were speedily exhausted, and died rapidly. Nearly one hundred horses were employed; they were of good quality; their average height was 15 hands ¼ inch, and their weight about 10½ cwts., and they cost from 20*l.* to 40*l.* each. They had as much corn as they could eat, and were well attended to.

The total quantity of work done by the horses, and its cost, was as under:—

	tons.
Registered quantity of water drawn 104 feet, the average height, 28,220,800 gallons - - - - - - - - -	128,535
Do. earth, 3,500 yds. 1 ton 6 cwt. per yard - - -	4,550
Total weight drawn to the surface - -	133,955

Total cost of horse labour, including a boy to drive each horse, 1,585*l.* 15*s.* 3*d.*, or 2·86*d.* per ton the average height of 104 ft.

Mr. Palmer made some experiments on the amount of work performed by horses tracking boats on canals. On the upper end of the mast of the boat a pulley was hung; over this the towing rope was passed, with the means of suspending to its extremity given weights, so as exactly to balance the power exerted by the horse.

The results arrived at by these means were so various, that he could not deduce any average conclusions, as the power exerted varied between 30 lbs. and 120 lbs., the power diminishing as the speed was increased. He thought that 2½ miles was too high an average estimate, and that it should not exceed 2 miles per hour, although in all estimates of horse power, the speed was considered to be at an average of 2½ miles per hour, and all experiments were reduced to that standard.

Mr. Hawkins, some years since, had made numerous inquiries respecting the work done by horses in drawing upon common turnpike roads, and found that four good horses could draw an ordinary stage-coach with its complement of passengers, at the rate of ten miles an hour; that if they ran stages 10 miles in the hour, the horses must rest one day in each week; that good horses, so worked, would last only five years, each horse drawing about half a ton. He had been informed by waggoners, that good horses would walk at the rate of 2½ miles per hour, for twelve hours out of twenty-four, making 30 miles a day; and that they would continue to do such work day by day, each horse drawing one ton, for many years, provided they had not been worked hard when young.

It is desirable to know the average speed at which the different rates of work had been performed; this was essential in order to found any calculation upon the results given. Coach proprietors calculated that at a speed of 10 miles per hour, a horse was required for every mile going and returning, so that one horse was kept for every mile of road. Now supposing a four-horse coach, with an average load, to weigh 2 tons, the load for each horse was 10 cwts.; whereas in the case of a horse drawing a cart, the gross load frequently amounted to 2 tons, but the speed was reduced to 2½ miles per hour, at which pace he conceived that 16 miles per day might be considered a fair day's work; this therefore was double the distance with four times the load, or eight times the coach work, but with a heavier horse.

The law that the quantity of work done was as the square root of the velocity,—or as the cube root of the velocity, in equal times, — is confined to work upon canals, or bodies moving through the water.

Mr. Rennie had tried some experiments on the force of traction of the boats on the Grand Junction Canal. The towing rope is attached to a dynamometer, which had previously been attested by weights.

The horse, although urged at first starting, was afterwards allowed to fall into his natural speed, which was 2½ miles per hour on the average of 20 miles. The maximum speed was 4 miles, and the minimum 2 miles, per hour. The dynamometer indicated an average of 108 lbs., which was capable of overcoming the resistance of the loaded barge of 25 tons, being in the ratio of 15·00. The weight of the horse was about 11 cwts.

He also tried many experiments upon a fast boat, lent to him in 1833 by the late Colonel Page. These experiments were principally made in order to ascertain the comparative resistance of vessels moving through water at different velocities, and the Grand Junction Canal afforded a convenient opportunity of undertaking them.

The boat was 70 feet in length, 4 feet in breadth, and drew 9 inches of water.

The traction indicated by the dynamometer the following resistance: —

Miles per hour.		lbs.
At 2½ the resistance was		20
3	„	27
3½	„	30
4	„	50
4½	„	60
5	„	70 to 75

One horse was employed in these experiments.

Miles per hour.		lbs.
At 6 the resistance was		97 to 214
7	„	250
8	„	336
9·69	„	411
10	„	375
11½	„	392
Average		336

Two horses were employed in these experiments.

Stakes were fixed near the margin of the canal, so as to ascertain the rise and fall of the wave caused by the boat in passing; and it was observed that when a boat passed with a velocity of from 4 to 6 miles per hour, the rise of the wave was 5 inches, and the fall 5 inches, making a wave of 10 inches in depth; and when the velocity was 11¼ miles, the rise was reduced to 2¼ inches, and the fall to 2¼ inches.

Great difference existed in the power of horses, their weights and structure; and the large dray horses used by Messrs. Barclay, Perkins, and Co. did a full average duty as assumed by Boulton and Watt; but considering the average power of strong and weak animals, he had adopted 22,000 lbs. raised 1 foot high as the standard; much, however, depended on the nature of the work performed.

Mr. Davidson has given the following statement of the work performed by a London brewer's horse per day; the cost of feed and of wear and tear per horse per annum being derived from actual experience among a large number of horses at Messrs. Truman, Hanbury, and Co.'s. brewery. The feed, &c., is supposed to have cost the same per quarter per truss, &c., each year.

Years.	Pounds Weight drawn 6½ Miles per Horse per Day.	Pounds Weight drawn 6½ Miles per Horse returning per Day.	Average Pounds Weight drawn 13 Miles per Horse per Day.	Cost of Feed and Straw per Horse per Annum.	Difference per Horse of Horses bought and sold per Annum.
1835	5,148 lbs.	1,716 lbs	3,342 lbs.	£43 2 7	£10 0 3
1836	5,072	1,767	3,389	43 16 6	9 18 0
1837					
1838	5,057	1,698	3,377	41 18 0	9 15 9
1839	5,287	1,740	3,513	42 9 11	9 7 1
1840	5,786	1,820	3,803	46 11 7	7 17 11
1841	5,311	1,750	3,530	45 0 1	10 16 11
1842	5,263	1,740	3,501	47 0 9	10 8 0
Total	36,924	12,171	24,455	309 19 5	68 3 11
Average 7 yrs. nearly	5,275	1,738	3,506	44 5 7	9 14 10

Mr. Beardmore mentions a case which occurred in a work near Plymouth, which he believed would give the fair value of the work actually performed daily by a horse for a considerable period.

A quarry-waggon, weighing 2½ tons, carrying an average load of stone of 5¾ tons, was drawn by one horse along a railway 960 feet in length, 260 of it being level, and the remaining 700 feet having an inclination of 1 in 138. During 48 working days the number of trips was 1,302, or an average of 27·1 trips each day; the time of performing each trip was 4 minutes, or at a speed of 2·72 miles per hour; and the total weight drawn, including that of the waggons, was 23,959,600 lbs.

Repeated experiments proved, that upon the incline of 1 in 138 the waggons in their ordinary working state would just remain stationary; the friction was therefore assumed to be 16·2 lbs. per ton; by calculation it was found that the horse raised 39,320 lbs. 1 foot high per minute during the 8 working hours each day: the useful effect, or net amount of stone carried, being 21,738 lbs. raised 1 foot high per minute. This difference between the work done and the useful effect arose from the necessary strength and weight of the waggons.

The animal employed was a common Devonshire cart-horse, 8 years old, 15 hands high, and weighed 10¾ cwts; he continued doing the same work throughout a whole summer, remaining in good condition; but a lighter horse was found unequal to it.

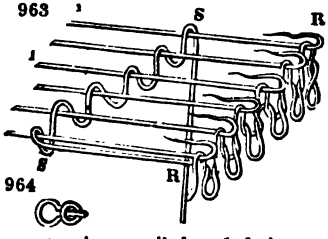
HORSESHOES. The ordinary method of making these is well known. There has however been lately introduced with much success a machine for making horseshoes. One of these machines has been erected at Chillington Ironworks, Wolverhampton, by the inventor, Mr. Henry Burden, of Troy, New York. As early as 1835 he took out a patent for a machine for making horseshoes, which he improved upon in 1843, and this was turned to practical account by the production of a considerable number of horseshoes. The present machine, however, which was patented in 1857, is entirely different from the former ones, and is a very remarkable piece of mechanism. In the previous machines the piece of iron bar of which the shoe was to be made was rolled into shape before being bent, and the pressure of the rollers being in the direction of its length, the bar, when it was pressed, was naturally rather extended in length than width, and the widening which is required at the crown of the shoe was not properly effected. By the present plan the bar, after being heated, enters the machine by a feeding apparatus, a piece of the required length is cut off, and, by a stroke from a piece of steel, shaped like the inside of a horseshoe, is bent, and falls upon a die on a wheel beneath, corresponding to one on a cylinder above,

and thus acquires by pressure the desired shape, two lateral strikers at the same moment hitting the extremities, or heels, of the shoe, and driving them inwards into the required shape. Thence it passes between another pair of dies, where it is stamped, and by an ingenious arrangement is flattened from the curled shape which the wheel gives it as it falls at the mouth of the machine. The shoes thus made are remarkable for their exactness in shape and in the position of the holes — a most important point with regard to the safety of horses' feet; and they can be produced, when the machine is in proper order, at the rate of 60 per minute, which is more than two men can forge in a day, and the superiority over shoes forged by hand is very striking. As the bar is bent before being pressed in the die, the pressure at the crown is in the direction of the width, and hence the widening is readily effected.

HOSIERY. (*Bonneterie*, Fr.; *Strumpfweberei*, Germ.) The *stocking frame*, which is the great implement of this business, though it appears at first sight to be a complicated machine, consists merely of a repetition of parts easily understood, with a moderate degree of attention, provided an accurate conception is first formed of the nature of the hosiery fabric. This texture is totally different from the rectangular decussation which constitutes cloth, as the slightest inspection of a stocking will show; for this, instead of having two distinct systems of thread, like the warp and the weft, which are woven together by crossing each other at right angles, the whole piece is composed of a single thread united or looped together in a peculiar manner, which is called stocking-stitch, and sometimes chain-work.

This is best explained by the view in *Fig.* 963. A single thread is formed into a number of loops or waves, by arranging it over a number of parallel needles, as shown at R; these are retained or kept in the form of loops or waves, by being drawn or looped through similar loops or waves formed by the thread of the preceding course of the work, S. The fabric thus formed by the union of a number of loops is easily unravelled, because the stability of the whole piece depends upon the ultimate fastening of the first end of the thread; and if this is undone, the loops formed by that end will open, and release the subsequent loops one at a time, until the whole is unravelled, and drawn out into the single thread from which it was made. In the same manner, if a thread in a stocking piece fails, or breaks at any part, or drops a stitch, as it is called, it immediately produces a hole, and the extension of the rest can only be prevented by fastening the end. It should be observed that there are many different fabrics of stocking stitch for various kinds of ornamental hosiery, and as each requires a different kind of frame or machine to produce it, we should greatly exceed our limits to enter into a detailed description of them all. That species which we have represented in *fig.* 963 is the common stocking-stitch used for plain hosiery, and is formed by the machine called the common stocking-frame, which is the groundwork of all the others. The operation, as we see, consists in drawing the loop of a thread successively through a series of other loops, so long as the work is continued, as is very plainly shown for one stitch in *fig.* 964.

963



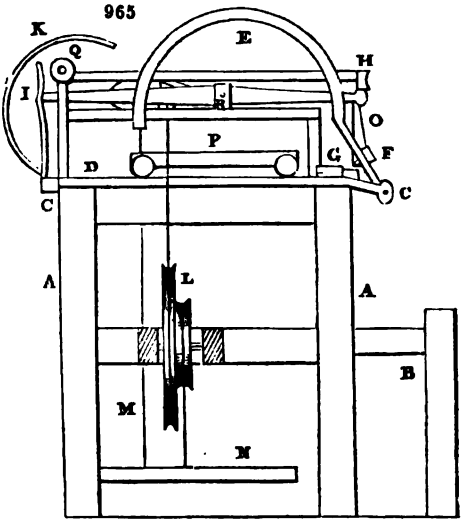
964

There is a great variety of different frames in use for producing various ornamental kinds of hosiery. The first, which forms the foundation of the whole, is that for knitting plain hosiery, or the common stocking-frame.

Of this valuable machine, the invention of Mr. Lee of Cambridge, a side elevation is given in *fig.* 965, with the essential parts. The framing is supported by four upright posts, generally of oak, ash, or other hard wood. Two of these posts appear at A A, and the connecting cross rails are at C C. At B is a small additional piece of framing, which supports the hosier's seat. The iron-work of the machine is bolted or screwed to the upper rails of the framework, and consists of two parts. The first rests upon a sole of polished iron, which appears at D, and to which a great part of the machinery is attached. The upper part, which is generally called the carriage, runs upon the iron sole at D, and is supported by four small wheels or trucks, as they are called by the workmen. At the upper part of the back standard of iron are joints, one of which appears at Q; and to these is fitted a frame, one side of which is seen extending to H. By means of these joints the end at H may be depressed by the hosier's hand, and it returns, when relieved, by the operation of a strong spring of tempered steel, acting between a cross bar in the frame, and another below. The action of this spring is very apparent in *fig.* 966. In the front of the frame, immediately opposite to where the hosier sits, are placed the needles which forms the loops. These needles, or rather hooks, are more or less numerous, according to the coarseness or fineness of the stocking; and this, although unavoidable, proves a very considerable abatement of the value of a stocking-frame. In almost every other machine (for example, those em-

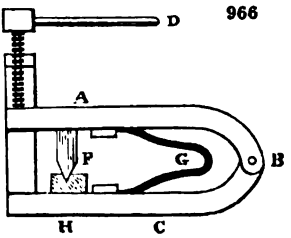
ployed in spinning or weaving), it is easy to adapt any one either to work coarser or finer work, as it may be wanted. But in the manufacture of hosiery, a frame once finished, is limited for ever in its operation to the same quality of work, with this exception, that by changing the stuff, the work may be made a little more dense or flimsy; but no alteration in the size or quantity of loops can take place. Hence where the manufacture is extensively prosecuted, many frames may be thrown idle by every vicissitude of demand; and where a poor mechanic does purchase his own frame he is for ever limited to the same kind of work. The gauge, as it is called, of a stocking-frame is regulated by the number of loops contained in three inches of breadth, and varies very much; the coarsest frames in common use being about what are termed Fourteens, and the finest employed in great extent about Forties. The needles are of iron wire, the manufacture of which is very simple; but long practice in the art is found necessary before a needle-maker acquires the dexterity which will enable him both to execute his work well, and in sufficient quantity to render his labour productive.

965



The process of making the needles is as follows:—Good sound iron wire, of a proper fineness, is to be selected; that which is liable to split or splinter, either in filing, punching, or bending, being totally unfit for the purpose. The wire is first to be cut into proper lengths, according to the fineness of the frame for which the needles are designed, coarse needles being considerably longer than fine ones. When a sufficient number (generally some thousands) have been cut, the wire must be softened as much as possible. This is done by laying them in rows in a flat iron box, about an inch deep, with a close cover; the box being filled with charcoal between the strata of wires. This box, being placed upon a moderate fire, is gradually heated until both the wires and charcoal have received a moderate red heat, because, were the heat increased to what smiths term the white heat, the wire would be rendered totally unfit for the subsequent processes which it has to undergo, both in finishing and working. When the box has been sufficiently heated, it may be taken from the fire, and placed among hot ashes until both ashes and box have gradually cooled; for the slower the wires cool, the softer and easier wrought they will be. When perfectly cool, the next process is to punch a longitudinal groove in the stem of every needle, which receives the point or barb, when depressed. This is done by means of a small engine worked by the power of a screw and lever. The construction of these engines is various; but a profile elevation of one of the most simple and commonly used will be found in *fig.* 966. It consists of two very strong pieces of malleable iron, represented at A and C, and these two pieces are connected by a strong well-fitted joint at B. The lower piece, or sole of the engine at C, is screwed down by bolts to a strong board or table, and the upper piece A will then rise or sink at pleasure, upon the joint B. In order that A may be very steady in rising and sinking, which is indispensable to its correct operation, a strong bridle of iron, which is shown in section at E, is added to confine it, and direct its motion. In the upper part of this bridle is a female screw, through which the forcing screw passes, which is turned by the handle or lever D. To the sole of the engine C is fixed a bolster of tempered steel, with a small groove to receive the wire which is to be punched; and in the upper or moving part A, is a sharp chisel, which descends exactly into the groove, when A is depressed by the screw. These are represented at F, and above H. At G is a strong spring, which forces up the chisel when the pressure of

966



the screw is removed. The appearance of the groove, when the punching is finished, will be rendered familiar by inspecting *fig.* 972, p. 471. When the punching is finished, the wires are to be brought to a fine smooth point by filing and burnishing, the latter of which should be very completely done, as, besides polishing the wire, it tends greatly to restore that spring and elasticity which has been removed by the previous operation of softening. The wire is next to be bent, in order to form the hook or barb; and this is done with a small piece of tin plate bent double, which receives the point of the wire, and by its breadth regulates the length of the barb. The stem of the needle is now flattened with a small hammer, to prevent it from turning in the tin socket in which it is afterwards to be cast; and the point of the barb being a little curved by a pair of small plyers, the needle is completed.

In order to fit the needles for the frame, they are now cast into the tin sockets or leads as they are called by the workman; and this is done by placing the needles in an iron mould, which opens and shuts by means of a joint, and pouring in the tin while in a state of fusion. In common operations, two needles are cast into the same socket. The form of the needle, when complete and fitted to its place in the frame, will be seen in *fig.* 967, which is a profile section of the needle-bar exhibiting one needle. In this figure a section of the pressure is represented at F; the needle appears at G, and the socket or level at K. At H, is a section of the needle-bar, on the fore part of which is a small plate of iron called a verge, to regulate the position of the needles. When placed upon the bar resting against the verge, another plate of iron, generally lined with soft leather, is screwed down upon the sockets or leads, in order to keep them all fast. This plate and the screw appear at I. When the presser at F is forced down upon the barb, this sinks into the groove of the stem, and the needle is shut; when the presser rises, the barb opens again by its own elasticity.

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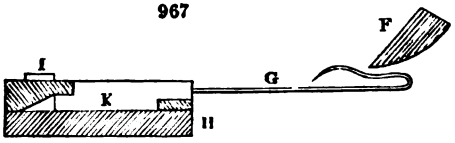

The needles or hooks being all properly fitted, the next part of the stocking-frame to which attention ought to be paid, is the machinery for forming the loops; and this consists of two parts. The first of these, which sinks between every second or alternate needle, is represented at O, *fig.* 965, and is one of the most important parts of the whole machine. It consists of two moving parts; the first being a succession of horizontal levers moving upon a common centre, and called jacks, a term applied to vibrating levers in various kinds of machinery as well as the stocking-frame. One only of these jacks can be represented in the profile *fig.* 965; but the whole are distinctly shown in a horizontal position in *fig.* 968; and a profile upon a very enlarged scale is given in *fig.* 969. The jack shown in *fig.* 965, extends horizontally from O to I, and the centre of motion

968

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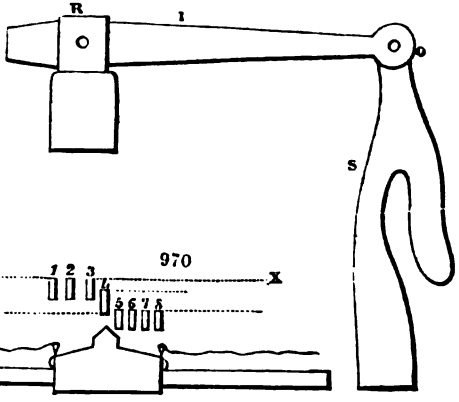

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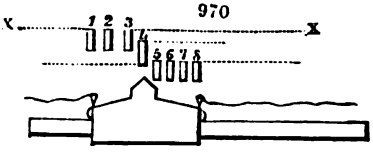
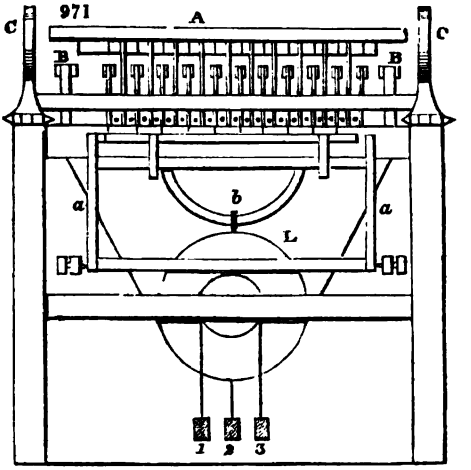
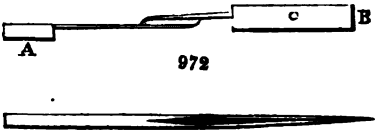


is at R. On the front, or right hand of the jack at O, is a joint suspending a very thin plate of polished iron, which is termed a sinker. One of these jacks and sinkers is allotted for every second or alternate needle. The form of the sinker will appear at S,

fig. 969; and in order that all may be exactly uniform in shape, they are cut out and finished between two stout pieces of iron, which serve as moulds or gauges to direct the frame-smith. The other end of the jack at I, is tapered to a point; and when the jacks are in their horizontal position, they are secured by small iron springs, one of which is represented at I, *fig.* 965, each spring having a small obtuse-angled notch to receive the point of the jack, against which it presses by its own elasticity. In *fig.* 969, the centre is at B, the pointed tail is omitted for want of room, the joint is at O, and the throat of the sinker, which forms the loop, is at S. The standards at B, upon which the jack moves, are called combs, and consist of pieces of flat smooth brass, parallel to, and equidistant from each other. The cross-bar B, which contains the whole, is of iron, with a perpendicular edge or rim on each side, leaving a vacancy between them, or a space to receive the bottom part or tails of the combs. The combs are then placed in the bar, with a flat piece of brass called a countercomb, between each, to ascertain and preserve their distances from each other. These countercombs are exactly of the same shape as the combs, but have no tails. When both combs and countercombs are placed in the bar, it is luted with clay so as to form a mould, into which is poured a sufficient quantity of melted tin. When the tin has had time to cool, the countercombs having no tails are easily taken out, and the combs remain well fastened and secured by the tin, which has been fused entirely round them. Thus they form a succession of standards for the jacks; and a hole being drilled through each jack and each comb, one polished wire put through serves as a common centre for the whole.

The jack sinkers being only used for every alternate or second needle, in order to complete this part of the apparatus, a second set of sinkers is employed. These are, in form and shape, every way the same as the jack sinkers, but they are jointed at the top into pieces of tin, all of which are screwed to the sinker bar, H, *fig.* 965; and thus a sinker of each kind descends between the needles alternately. By these sinkers the loops are formed upon all the needles, and the reason of two sets different in operation being employed, will be assigned in describing the mode of working the frame. The presser of the operation, of which something has already been said, appears at F; and of the two arms which support and give motion to it, one appears very plainly at E, its centre of motion being at C. The circular bend given to these arms, besides having an ornamental effect, is very useful, in order to prevent any part from interfering with the other parts which are behind, by elevating them entirely above them. The extremities of these arms at the termination of the bends behind, are connected by a cross bar, which has also a circular bend in the middle, projecting downwards for a reason similar to that already assigned. This bend is concealed in *fig.* 965, but visible in the front elevation, *fig.* 971. From the middle of the bend, the presser is connected with the middle treadle by a depending wire appearing at M, *fig.* 965, and thus, by the pressure of that treadle, the presser is forced down to close the barbs of the needle. The re-ascent of the presser is sometimes effected by means of a counterpoising weight passing over a pulley behind; and sometimes by the reaction of a wooden spring, formed of a strong hoop like that represented at K. The latter of these is preferred, especially by the Nottingham hosiers, because, as they assert, it makes the presser spring up with greater rapidity, and consequently saves time in working. How far this may be practically the case, it would be superfluous here to investigate; but it is obvious that the wooden spring, if very stiff, must add much to the hosier's exertion of his foot, already exercised against the united spring of all his barbs; and this inconvenience is



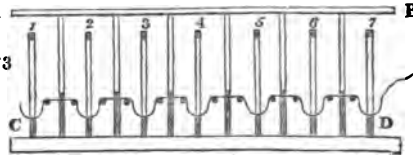


972

much complained of by those who have been accustomed to work with the counterpoise.

At L are two pulleys or wheels, of different diameters, moving upon a common centre, by which the jack sinkers are relieved from the back springs, and thrown downwards to form the loops upon the needles. About the larger wheel is a band of whipcord, passing twice round, the extremities of which are attached to what is called the slur, which disengages the jacks from the back springs. The smaller pulley, by another band, communicates with the right and left treadle; so that these treadles, when pressed alternately, turn the pulleys about in an inverted order. The directions of these bands also appear more plainly in the front elevation, *fig.* 971. The construction of the slur, and its effect upon the jacks, will also be rendered apparent by *fig.* 970. In this figure, eight jacks are represented in section, the tail part of three of which, 1, 2, 3, are thrown up by the slur in its progress from left to right; the fourth is in the act of rising, and the remaining four, 5, 6, 7, and 8, are still unacted upon, the slur not yet having reached them. As the slur acts in the direction of the dotted line X X, *fig.* 968, behind the centres of the jacks, it is hardly necessary to remark, that this forcing up of the tails must of course depress the joints by which the sinkers in front are suspended; the jack sinkers falling successively from the loops on every alternate needle, in the way represented at *fig.* 973, where both kinds of sinkers appear in section, the light part expressing what is above the point at which the throat of the sinker operates upon the thread, and the dark part what is below. The second set, or, as they are called, the lead sinkers, from the manner of joining them, and suspending them from the bar above, appear still elevated; the position of the bar being represented by the line A, B. But when these are pulled down to the level of the former by the operator's hands, the whole looping will be completed, and the thread C, D, which is still slack, will be brought to its full and proper degree of tension, which is regulated by stop screws, so as to be tempered or altered at pleasure. The sinking of this second set of sinkers may be easily explained by *fig.* 974. The direction of the sinkers is expressed by the line E; the bar from which they are suspended will be at A; the top frame is in the direction from A to B; the back standards at D, and the joint at B, is the centre of motion. If E is pulled perpendicularly downwards, the spring C will be contracted, and its upper extreme point, G, will be brought nearer to its lower extreme point F, which is fixed. Again, when the force which has depressed E is removed, the spring C will revert to its former state, and the sinkers will rise. The raising of the jack sinkers and jacks takes place at the same time, by the hosier raising his hands; and for the cause of this we must revert to *fig.* 968. The lead sinkers in rising lay hold of notches, which raise the extreme parts of the set of jacks Z, Z, which are called half-jacks. Between the extremities of these at Z Z, is a cross bar, which, in descending, presses all the intermediate jacks behind the common centre, and restores them to their original posture, where they are secured by the back springs, until they are again relieved by the operation of the slur recrossing at the next course.

973



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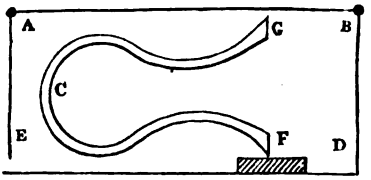
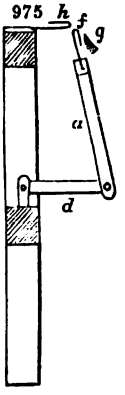


Working of the frame. — In order to work a frame, the whole apparatus being previously put into complete order, the hosier places himself on the seat B in front, and provides himself with a bobbin of yarn or stuff. This bobbin he places loosely on a vertical pin of wire, driven into one side of the frame contiguous to the needles, so that it may turn freely as the stuff is unwound from it. Taking the thread in his hand, he draws it loosely along the needles, behind the barbs, and under the throats of the sinkers. He then presses down one of the treadles to pass the slur along, and unlock the jacks from the back springs, that they may fall in succession. When this is done, the number of loops thus formed is doubled by bringing down the lead sinkers, and the new formed loops are lodged under the barbs of the needles by bringing forward the sinkers. The preceding course, and former fabric, being then again pushed back, the barbs are shut by depressing the middle treadle, and forcing down the presser upon the needles. The former work is now easily brought over the shut needles, after which, by raising the hands, both sets of sinkers are raised; the jacks are locked by the back springs, and the hosier goes on to another course.

From this it will be apparent, that the remark made in the outset is well founded, that there are in reality no complicated or difficult movements in the stocking-frame. Almost the whole are merely those of levers moving upon their respective fulcra, excepting that of the carriage which gives the horizontal motion to the sinkers, and that is merely an alternate motion on four wheels. Yet the frame is a machine which requires considerable experience and care, both to work it to advantage, and also to keep it in good order. This circumstance arises greatly from the small compass in which a number of moving parts must be included. Owing to this, the needles, unless cautiously and delicately handled, are easily bent or injured. The same circumstance applies with equal or greater force to the sinkers, which must be so very thin as to be easily injured. But as these must work freely, both in a perpendicular and horizontal direction between the needles, in a very confined and limited space, the slightest variation in either, from being truly and squarely placed, unavoidably injures the others. When a hosier, either ignorant of the mechanical laws of their relation to each other, or too impatient to wait for the assistance of another, attempts to rectify defects, he in most cases increases them tenfold, and renders the machine incapable of working at all, until repaired by some more experienced person. This circumstance has given rise to a set of men employed in this trade, and distinguished by the name of upsetters; and these people, besides setting new frames to work, have frequently more employment in repairing old ones injured by want of care or skill, than many country apothecaries, who live in unhealthy parishes, find in tampering with the disorders of mankind.

It seems unnecessary to go further into detail respecting a machine so well known, and which requires practical attention even more than most others. It may, therefore, be sufficient to describe shortly some of its varieties, the most simple and common of which is the rib stocking-frame.

Rib stocking-frame. —This frame, which, next to the common frame, is most extensively in use, is employed for working those striped or ribbed stockings, which are very common in all the different materials of which hosiery is formed. In principle it does not differ from the common frame, and not greatly in construction. The preceding general description will nearly apply to this machine with equal propriety as to the former; that part, however, by which the ribs or stripes are formed, is entirely an addition, and to the application of this additional machinery it may be proper to pay the chief attention, referring chiefly to *fig.* 971, which is a front elevation. This figure has been already referred to for the illustration of those parts of the machinery which are common to both, and those parts therefore require no recapitulation. The principle of weaving ribbed hosiery has considerable affinity to that of weaving that kind of cloth which is distinguished by the name of tweeling, for the formation of stripes, with some variation arising merely from the different nature of the fabric. In cloth weaving, two different kinds of yarn intersecting each other at right angles, are employed; in hosiery only one is used. In the tweeling of cloth, striped as dimity, in the cotton or kerseymere, and in the woollen manufacture, the stripes are produced by reversing these yarns. In hosiery, where only one kind of yarn is used, a similar effect is produced by reversing the loops. To effect this reversing of the loops, a second set of needles is placed upon a vertical frame, so that the bends of the hooks may be nearly under those of the common needles. These needles are cast into tin moulds, pretty similar to the former, but more oblique or bevelled towards the point, so as to prevent obstructions in working them. They are also screwed to a bar of iron, generally lighter than the other, and secured by means of plates: this bar is not fixed, but has a pivot in each end, by means of which the bar may have a kind of oscillatory motion on these pivots. Two frames of iron support this bar; that in which it oscillates being nearly vertical, but inclined a little towards the other needles. *Fig.* 975, which is a profile elevation, will serve to illustrate the relative position of each bar to the other. The lower or horizontal frame, the ends only of which can be seen in *fig.* 971, under *a a*, appears in profile in *fig.* 975. where it is distinguished by *d*. The vertical frame at *a* is attached to this by two centre screws, which serve as joints for it to move in. On the top of this frame is the rib-needle bar at *f*, in *figs.* 965 and 975, and one needle is represented in *fig.* 975 at *f*. At *g* is a small presser, to shut the barbs of the rib-needles, in the same manner as the large one does those of the frame. At *h* is one of the frame needles, to show the relative position of the one set to the other. The whole of the rib-bar is not fitted with needles like the other; for here needles are only placed where ribs or stripes are to be formed, the intervals being filled up with blank leads, that is to say, with sockets of the same shape as the others, but

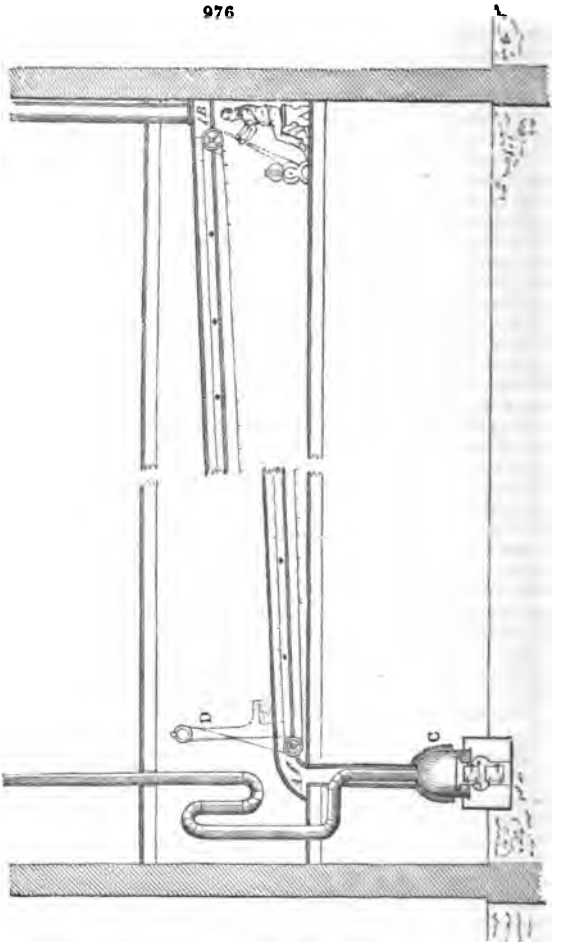


without needles; being merely designed to fill the bar and preserve the intervals. Two small handles depend from the needle bar, by which the oscillatory motion upon the upper centres is given. The rising and sinking motion is communicated to this machine by chains which are attached to iron sliders below, and which are wrought by the hosier's heel when necessary. The pressure takes place partly by the action of the small presser, and partly by the motion of the needles in descending. A small iron slider is placed behind the rib-needles, which rises as they descend, and serves to free the loops perfectly from each other.

In the weaving of ribbed hosiery, the plain and ribbed courses are wrought alternately. When the plain are finished, the rib-needles are raised between the others, but no additional stuff is supplied. The rib-needles intersecting the plain ones, merely lay hold of the last thread, and by again bringing it through that which was on the rib-needle before, give it an additional looping, which reverses the line of chaining, and raises the rib above the plain intervals, which have only received a single knitting.

HOT-FLUE is the name given in England to an apartment heated by stoves or steam pipes, in which padded and printed calicoes are dried hard. *Fig.* 976 repre-

976

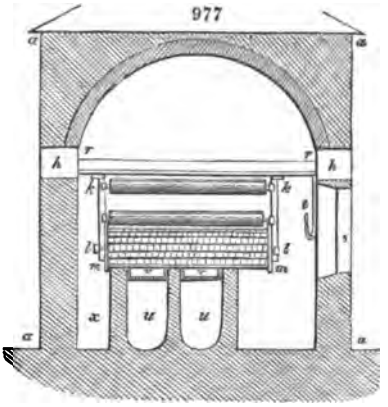


sents the simplest form of such a flue, heated by the vertical round iron stove C, from whose top a wide square pipe proceeds upwards in a slightly inclined direction, which receives the current of air heated by the body and capital of the stove. In this wide

channel there are pulleys, with cords or bands which suspend by hooks and conduct the web of calico from the entrance at B, where the operative sits, to near the point A, and back again. This circuit may be repeated once or oftener till the goods are perfectly dried. At D the driving pulley connected with the main shaft is shown. Near the feet of the operative is the *candroy* or reel upon which the moist goods are rolled in an endless web; so that their circulation in the hot-air channel can be continued without interruption, as long as may be necessary.

Fig. 977 is a cross section of the apparatus of the regular hot-flue, as it is mounted in the most scientific calico works of England, those of James Thomson, Esq., of Primrose, near Clitheroe, Lancashire. *a a a a* is an arched apartment, nearly 30 yards long, by 13 feet high, and 10 feet wide. Through about one half of this gallery there is a horizontal floor supported on arches, above which is the driest space, through which the goods are finally passed before they escape from the hot-flue, after they have been previously exposed to the hot but somewhat moist air of the lower compartment. A large square flue covered with cast-iron plates runs along the whole bottom of the gallery. It is divided into two long parallel vaults, whose sections are seen at *u*, *u*, *fig.* 977, covered with the cast-iron plates *v v*, grooved at their ends into one another. The thickness of these plates is increased progressively as they come nearer to the fireplace or furnace. There are dampers which regulate the draught, and of course the heat of the stove. *h h* are the air-passages or vent holes, left in the side walls, and which by means of a long iron rod, mounted with iron plates, may be opened or closed together to any degree. *k k* are the cast-iron supports of the tinned brass rollers which guide the goods along, and which are fixed to the cross pieces represented by *r r*, *fig.* 977. *l l* are iron bars for supporting the ventilators or fans (see FOUNDRY and VENTILATION). These fans are here enclosed within a wire grating. They make about 300 turns per minute, and expel the moist air with perfect effect. *s* indicates the position of the windows, which extend throughout the length of the building. *t* is a gas-light jet, placed at the side of each window to supply illumination for night work.

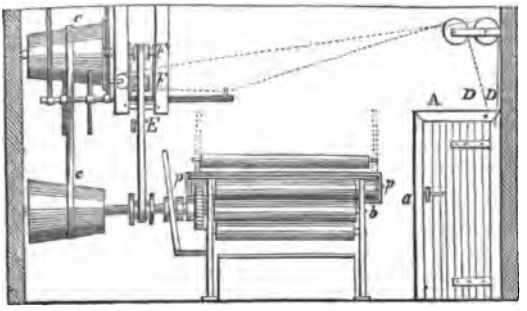
977



The piece is stretched along the whole extent of the gallery, and runs through it in the course of one minute and a half; being exposed during its passage to the heat of 212° Fahr.

In *fig.* 978, A is the iron door of entrance to the hot-flue gallery; at *b* is the padding machine, where the goods are imbued with the general mordant. The speed of this machine may be varied by means of the two conical drums *c c*, which drive it; since, when the band *c c* is brought by its forks, and adjusting screws, nearer to the narrow end of the lower drum, the cylinder upon the same shaft with the latter is driven quicker; and *vice versa*. Over D D the cords are shown for drawing the drum mechanism into gear with the main shaft band, F, F, E; or for throwing it out of gear. The pulleys F F carry the bands which transmit the motion to the padding machine. A cylindrical drum exterior to the hot-flue, covered with flannel, serves to receive the end of the series of pieces, and to draw them through the apartment. This mode of drying the padded calicoes requires for each piece of 28 yards three pounds of coals for the furnace when a fan is employed, and four pounds without it. See CALICO PRINTING.

978



HUNGARY WATER. Supposed to be named after a queen of Hungary, who used it as a cosmetic: it is prepared by distilling rosemary. See EAU DE COLOGNE.

HYACINTH. The name under which are included the transparent, bright-coloured varieties of zircon. Hyacinth differs from jargoon merely in colour, which is orange-red passing into poppy-red. Though not much worn at the present time it is a valuable gem, and makes a very superb ring-stone when of a bright tint and free from flaws. The larger pieces are sometimes made into seals. Hyacinths occur in the sand and alluvial deposits of certain rivers in Ceylon, also in the state of sand, mingled with various other substances, in the bed of a stream at Expailly (Haute Loire) in France, as well as in basalt near the same place. It is also found in volcanic tuff in Auvergne, in Bohemia, Saxony, the Tyrol, Transylvania, Greenland, in the zircon-syenite of Fredericks-värn in Norway, and in the iron mines of Arendal; also at Miask in the Urals, Vesuvius, at Santa Rosa in New Grenada, at Scalpay in Harris, Scotland, Egypt, the East Indies and elsewhere. The hyacinth-red varieties of zircon are sold by the inhabitants of Ceylon as inferior rubies.—H. W. B.

HYDRATES are compounds of the oxides, salts, &c., with water in definite or equivalent proportions. Thus slaked lime consists of one atom of quick-lime = 28, + one atom of water = 9, of which the sum is 37 on the hydrogen scale. "The very different functions performed by water in the various modes of combination it affects render it necessary to adopt a definite principle of nomenclature in this respect. . . . I shall employ the word *hydrate* only where the water is combined with a base, such as a metallic oxide, thus, hydrate of lime, hydrate of potash, hydrated oxide of lead." —*Kane.*

HYDRAULIC CEMENTS. See MORTAR.

HYDRAULIC CRANES. The application of water-pressure to cranes is due to Sir Wm. Armstrong. These are now so generally applied, that although the subject belongs properly to engineering, it is thought advisable to include some notice of these valuable and interesting machines in this work. A statement made, by the request of the British Association in 1854, by the inventor himself, so completely explains all the peculiarities of these cranes, that the paper is reproduced from the proceedings of the Association.

"The employment of water-pressure as a mechanical agent having recently undergone a great and rapid development, I may be permitted to make a few observations on the successive steps by which its present importance has been attained. In so doing I shall commence with the year 1846, in which, after many preliminary experiments, I succeeded in establishing, upon the public quay at Newcastle-upon-Tyne, the hydraulic crane which has formed the basis of what has since been effected.

"This crane both lifted the weight and swung round in either direction by the pressure of water, and was characterised, like all other hydraulic cranes since made, by remarkable precision and softness of movement, combined with great rapidity of action.

"The experiment thus made at Newcastle having proved satisfactory, I soon afterwards obtained authority, through the intervention of Mr. Hartley, the Dock Surveyor of Liverpool, to construct several cranes and hoists upon the same principle at the Albert Dock in that town, where they were accordingly erected, and have ever since continued in operation.

"The next place at which these cranes were adopted was Grimsby New Dock, where an important step in the advancement of this kind of machinery was made on the suggestion of Mr. Rendel, who pointed out its applicability to the opening and closing of dock gates and sluices, and instructed me to extend its application to those objects. An extensive system of water-pressure machinery was accordingly carried out at that dock, and the result afforded the first practical demonstration that the pressure of a column of water could be advantageously applied as a substitute for manual labour, not merely for the cranage of goods, but also to give safe and rapid effect to those mechanical operations which are necessary for passing ships through the entrances of docks.

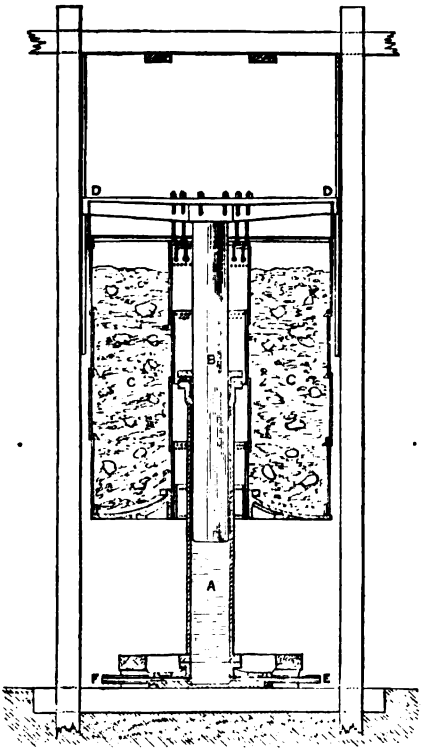
"In all these instances the moving column of water was about 200 feet in elevation. At Newcastle and Liverpool the supply was derived from the pipes communicating with the town reservoirs, but at Grimsby a tower was built for supporting a tank into which water was pumped by a steam-engine. In the former cases, the fluctuation of pressure, consequent upon the variable draught from the pipes for the ordinary purposes of consumption, proved a serious disadvantage; but this objection had no existence at Grimsby, where the tank upon the tower furnished a separate source of power, undisturbed by any interfering conditions. Nothing could be more effectual for its purpose than this tower; but, in the natural course of improvement, I was subsequently led to the adoption of another form of artificial head, which possessed the advantage of being applicable, at a comparatively small cost, in all situations, and

of lessening the size of the pipes and hydraulic machinery, by affording a pressure of greatly increased intensity.

"The apparatus thus substituted for a water tower I named "*the Accumulator*," from the circumstance of its accumulating the power exerted by the engine in charging it. The accumulator is, in fact, a reservoir giving pressure by *load* instead of by *elevation*, and its use, like that of every provision of this kind, is to equalise the strain upon the engine in cases where the quantity of power to be supplied is subject to great and sudden fluctuations.

"The construction of the accumulator is exhibited in *fig.* 979, and needs but little explanation. A, cylinder, B, plunger; C C, loaded weight case; D, D, guides for ditto; E, pipe from pumping engine; F, pipe to hydraulic machine. It consists of a large cast-iron cylinder, fitted with a plunger, from which a loaded weight case is suspended, to give pressure to the water injected by the engine. The load upon the plunger is usually such as to produce a pressure in the cylinder equal to a column of 1500 feet in elevation, and the apparatus is made sufficiently capacious to contain the largest quantity of water which can be drawn from it at once by the simultaneous action of all the hydraulic machines with which it is connected. Whenever the engine pumps more water into the accumulator than passes direct to the hydraulic machines, the loaded plunger rises and makes room in the cylinder for the surplus; but when, on the other hand, the supply from the engine is less, for the moment, than the quantity required, the plunger, with its load, descends and makes up the deficiency out of store.

979



"The accumulator also serves as a regulator to the engine; for when the loaded plunger rises to a certain height, it begins to close a throttle-valve in the steam-pipe, so as gradually to reduce the speed of the engine until the descent of the plunger again calls for an increased production of power.

"The introduction of the accumulator, which took place in the year 1851, gave a great impulse to the extension of water-pressure machinery, which is now either already applied, or in course of being applied, to the purpose of cranage throughout all the great dock establishments in London, as also to a considerable extent in Liverpool and other places. I have also applied it extensively to railway purposes, chiefly under the direction of Mr. Brunel, who has found a multitude of cases, involving lifting or tractive power, in which it may be made available. Most of these applications are well exemplified at the new station of the Great Western Railway Company in London, where the loading and unloading of trucks, the hoisting into warehouses, the lifting of loaded trucks from one level to another, the moving of turn-tables, and the hauling of trucks and traversing machines are all performed, or about to be so, by means of hydraulic pressure supplied by one central steam-engine with connected accumulators. Mr. Rendel also, after having successfully adopted the low-pressure system to the working of the gates and shuttles at Grimsby, has since applied the high-pressure, or accumulator system, to the same purposes at other new docks, and a similar adaptation is being made by other eminent engineers at most of the new docks now in course of construction.

"I have also adapted hydraulic machinery to the opening and closing of swing-bridges and draw-bridges of large dimensions; and, in fact, there is scarcely any mechanical operation to which human labour has been hitherto applied as a mere

moving power, which may not be efficiently performed by means of water-pressure emanating from a steam-engine and accumulator. Even if hand-labour be retained as the source of the power, the intervention of an accumulator will in many cases both economise labour and increase despatch. For example, a pair of heavy dock-gates requires the constant attendance of a considerable number of men, whose labour is only called into action occasionally, viz. when the gates are being opened or closed. Now, if an accumulator, charged by hand-pumps, were used, the labour employed would be constant, instead of occasional, and the power collected in the accumulator by the continuous process of pumping would be given out in a concentrated form, and thus the ultimate result would be effected with fewer hands and greater despatch than where manual labour is directly applied.

"The form of pumping-engine which I generally use for charging the accumulator is represented in *fig.* 980. It consists of a horizontal steam-cylinder, with two

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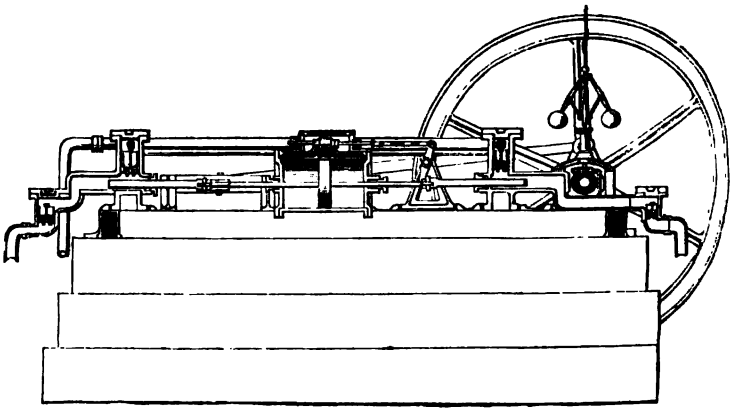

force-pumps connected directly with the piston. These force-pumps are supplied with water from a cistern over the engine-room, into which the water discharged by the cranes is generally brought back by a return-pipe, so that the water is not wasted, but remains continuously in use.

"With a pressure representing a column of 1500 feet, the loss of head by friction in the pipes forms so small a deduction from the entire column as to be a matter of no consideration, and consequently the distance at which the engine may be situated from the points where the hydraulic machines may be placed is of little importance, except as regards the cost of the pipe. It is advisable, however, if the pipe be very long, to apply an accumulator at each extremity, so as to charge the pipe from both ends.

"With regard to the mechanism of hydraulic cranes, the arrangement which I first adopted, and have ever since adhered to, consists of one or more hydraulic presses, with a set of sheaves, used in the inverted order of blocks and pulleys, for the purpose of obtaining an extended motion in the chain from a comparatively short stroke of the piston. This construction, which characterises nearly all the varieties of the hoisting and hauling machines to which I have applied hydraulic pressure is exhibited in *fig.* 981, which represents one of these presses with sheaves attached, to multiply the motion fourfold. In cases where the resistance to be overcome varies very considerably, I generally employ three such cylinders, with rams or pistons acting either separately or conjointly upon the same set of multiplying sheaves, according to the amount of power required.

"In hydraulic cranes the power is applied, not only for lifting the load, but also for swinging the jib, which latter object is effected by means of a rack or chain operating on the base of the movable part of the crane, and connected either with a cylinder and piston having alternate motion, like that of a steam-engine, or with two presses appl ed to produce the same effect by alternate action.

"The absence of any sensible elasticity in water renders the motions resulting from its pressure capable of the most perfect control, by means of the valves which regulate the inlet and outlet passages of the machines; but this very property, which gives so much certainty of action, tends to cause shocks and strains to the machinery, by resisting the momentum acquired by the moving parts. Take, for example, the case

of an hydraulic crane, swinging round with a load suspended on the jib, the motion being produced by the water entering on one side of a piston and escaping from the

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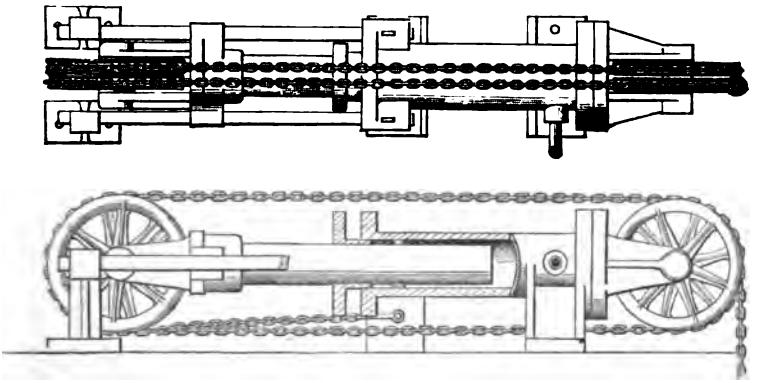


other. Under such circumstances, if the water-passages be suddenly closed by the regulating valve, it is obvious that the piston, impelled forward by the momentum of the loaded jib, but met by an unyielding body of water deprived of outlet, would be brought to rest so abruptly, as to cause, in all probability, the breakage of the machine. So also, in lowering a heavy weight with considerable velocity, if the escape-passage be too suddenly closed, a similar risk of injury would arise from the abrupt stoppage of the weight, if a remedy were not provided; but these liabilities are effectually removed by applying, in connection with the water-passages to the cylinder, a small clack-valve, opening upwards against the pressure into the supply-pipe, so as to permit the pent-up water in the cylinder to be pressed back into the pipe whenever it becomes exposed to a compressive force exceeding the pressure on the accumulator. By this means all jerks and concussions are avoided, and a perfect control over the movement of the machine is combined with great softness of action.

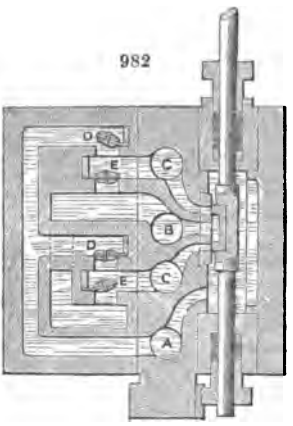
"With regard to the kind of valves used for water-pressure machines, I find that either lift-valves or slide-valves may be effectually applied, and kept tight under heavy pressures, provided that sand be excluded from the water, and the valves be made of proper material.

"In cases where a more prolonged movement is required than multiplying sheaves will conveniently afford, I employ rotative machines of various constructions. For heavy-pressures, such as an accumulator affords, an arrangement consisting of three plungers, connected with a triple crank, and bearing a general resemblance to a three-throw plunger pump, is well adapted for the purpose. The admission and exhaust valves are mitred spindles, pressed down by weights and levers, and lifted in proper rotation by cams fixed for that purpose upon a separate shaft; and these valves are associated with relief-clacks, to obviate the concussion which would otherwise be liable to take place at the turn of each stroke.

"The liability of water-pressure machinery to be deranged by frost has often been adduced as an objection to its use; and upon this point I may observe—first, that I have never experienced any interference from this cause when the machines were placed, as they generally are, beneath the surface of the ground, or within a building; and secondly, that when they are unavoidably exposed, all risk may be prevented by letting out the water in frosty weather whenever the machines cease working.

"When the moving power consists of a natural column of water, the pressure rarely exceeds 250 or 300 feet, and in such cases I have employed for rotative action a pair of cylinders and pistons, with slide-valves, resembling in some degree those of a high-pressure engine, but having relief-valves, to prevent shock at the turn of the stroke. *Fig.* 982 shows a slide-valve adapted for the turning apparatus of a crane, but the relief-clacks of which are equally applicable to a water-pressure engine of the construction in question. Two of these clacks open against the pressure in the supply-pipe, so as to afford an escape for the water, which would otherwise be shut up in the cylinder when the exhaust port closes, and the other two communicate with the discharge-pipe, so as to draw in a portion of waste water to fill up the small vacancy which would otherwise be left in the cylinder on the closing of the admission port. A, supply pipe; B, exhaust pipe; C C, pipes to cylinder; D D, clacks opening against

pressure; E E, clacks opening from exhaust. About four years ago I constructed four hydraulic engines upon this principle at Mr. Beaumont's lead mines in Northumberland, at the instance of Mr. Sopwith, Mr. Beaumont's well-known agent, and two more have recently been added at the same place. They are used for crushing ore, for hoisting materials from the mines, for pumping water, and for driving a circular saw and other machinery. See WATER-PRESSURE MACHINERY, *applied to mines*.



"If in progress of time railways should be generally extended into mountainous districts, so as to render them accessible for manufacturing purposes, the rapid streams which abound in such localities will probably become valuable sources of motive power, and a wider field may then be afforded for the application of water-pressure engines to natural falls.

"The object, however, which I have chiefly had in view since I first gave attention to this subject, has been to provide, in substitution of manual labour, a method of working a multiplicity of machines, intermittent in their action, and extending over a large area, by means of transmitted power produced by a steam-engine and accumulated at one central point. The common mode of communicating power by shafting could only be applied in cases where the machines were collected within a small compass, and where the accumulation of power necessary to meet varying resistance did not exceed that which a fly-wheel would afford. Compressed or exhausted air was almost equally inapplicable to the purposes I contemplated, in consequence of the many objections which its elasticity involves, as well as the liability to leakage, which, in an extended system of pipes and machines, requiring a multitude of joints, valves, and fitting surfaces, would form an insurmountable difficulty. But the use of water as a medium of transmission is free from all these objections, and its fitness for the purpose intended is now thoroughly established by the results which have been obtained."

HYDRAULIC MACHINERY for mines. See WATER AND WATER-PRESSURE ENGINES, TURBINE.

HYDRAULIC PRESS. See WATER PRESSURE MACHINERY.

HYDRIODIC ACID (*Acide Hydriodique*, Fr.; *Hydriodsäure*, Germ.) is an acid formed by the combination of 127 parts of iodine with 1 part of hydrogen by weight, and by measure equal volumes of iodine vapour and hydrogen combined without condensation. It is obtained pure and in the gaseous state by introducing into a glass tube, closed at one end, a little iodine, then a small quantity of roughly-powdered glass moistened with water, upon this a few small fragments of phosphorus, and lastly more glass; this order, iodine, glass, phosphorus, glass, is repeated until the tube is two-thirds filled. A cork and narrow bent tube are then fitted and gentle heat applied, when the hydriodic acid is liberated, and may be collected in dry bottles by the displacement of air. Another process is to place in a small retort 10 parts of iodide of potassium with 5 of water, add 20 parts of iodine, then drop in cautiously 1 part of phosphorus cut into small pieces, and apply a gentle heat; hydriodic acid will be formed abundantly, and may be collected as before stated. The following equation expresses the reaction:

$$2KI + 5I + P + 8HO \text{ yield } 2KO,HO,PO^5 + 7HI.$$

Hydriodic acid greatly resembles hydrochloric acid; it is colourless, and highly acid, it fumes in the air, and is very soluble in water. Its density is 4·4, and under strong pressure condenses to a yellowish liquid, which solidifies at 60° Fahr.

Hydriodic acid in solution is much more easily prepared, by suspending iodine in water, and passing a stream of washed hydrosulphuric acid through it until the colour disappears; it is then heated to expel the hydrosulphuric acid, then allowed to rest, when it may be decanted from the precipitate of sulphur. The reaction consists simply in the displacement of the sulphur by the iodine, $HS + I = HI + S$.

This liquid may be evaporated until it acquires a density of 1·7, when it consists of $HI + 11HO$. It then distils at 262° Fahr. without decomposition. The solution cannot be long kept, it being decomposed by the oxygen of the air with the liberation of iodine, which imparts a dark colour to it. Chlorine decomposes it instantly, with liberation of the iodine.

The solution of hydriodic acid and of the iodides possess the power of dissolving a considerable quantity of iodine, forming a dark solution. — H. K. B.

HYDROBROMIC ACID. HBr. See BROMINE.

HYDRO-CARBON. See CARBURETTED HYDROGEN

HYDROCHLORIC ACID. (*Chlorhydrique*, Fr.; *Salzsaüre*, Germ.) A compound of chlorine and hydrogen which is a colourless gas of a peculiar suffocating, pungent odour; it reddens vegetable blues, but possesses no bleaching properties. The solution of hydrochloric acid in water is the MURIATIC ACID and SPIRIT OF SALT of commerce; anciently *Marine Acid*. 2 volumes of chlorine and 2 volumes of hydrogen combine to form 4 volumes of this acid. HCl; eq. 36·5. It is best prepared by heating a mixture of 6 parts of chloride of sodium (*common salt*) and 10 parts of concentrated sulphuric acid, previously diluted with 4 parts of water, in a capacious glass retort, connected with a set of Woolfe's bottles. This acid is extracted on a large scale from sea-salt, by the action of sulphuric acid and a moderate heat; but it was originally obtained from the salt by exposing a mixture of it and of common clay to ignition in an earthen retort. The acid gas which exhales is rapidly condensed by water. 100 cubic inches of water are capable of absorbing no less than 48,000 cubic inches of the acid gas, whereby the liquid acquires a specific gravity of 1·2109: and a volume of 142 cubic inches. This vast condensation is accompanied with a great production of heat; whence it becomes necessary to apply artificial refrigeration, especially if so strong an acid as the above is to be prepared. In general, the muriatic acid of commerce has a specific gravity varying from 1·15 to 1·20, and contains, for the most part, considerably less than 40 parts by weight of acid gas in the hundred. The above stronger acid contains 42·68 per cent. by weight; for since a cubic inch of water, which weighs 252·5 grains, has absorbed 480 cubic inches = 188 grains of gas; and 252·5 + 188 = 440·5; then 440·5 : 188 :: 100 : 42·68. In general a very good approximation may be found to the percentage of real muriatic acid, in any liquid sample, by multiplying the decimal figures of the specific gravity by 200. Thus, for example, at 1·162 we shall have by this rule 0·162 × 200 = 32·4, for the quantity of gas in 100 parts of the liquid. Muriatic acid gas consists of chlorine and hydrogen combined, without condensation, in equal volumes. Its specific gravity is 1·247, air = 1·000.

By sealing up muriate of ammonia and sulphuric acid, apart, in a strong glass tube re-curved, and then causing them to act on each other, Sir H. Davy procured liquid muriatic acid. He justly observes, that the generation of elastic substances in close vessels, either with or without heat, offers much more powerful means of approximating their molecules than those dependent on the application of cold, whether natural or artificial; for as gases diminished only $\frac{1}{480}$ in volume for every degree of Fahrenheit's scale, beginning at ordinary temperatures, a very slight condensation only can be produced by the most powerful freezing mixtures, not half so much as would result from the application of a strong flame to one part of a glass tube, the other part being of ordinary temperature; and when attempts are made to condense gases into liquids by sudden mechanical compression, the heat instantly generated presents a formidable obstacle to the success of the experiment; whereas, in the compression resulting from their slow generation in close vessels, if the process be conducted with common precautions, there is no source of difficulty or danger; and it may be easily assisted by artificial cold, in cases where gases approach near to that point of compression and temperature at which they become vapours.—*Phil. Trans.* 1823.

The muriatic acid of commerce has usually a yellowish tinge, but when chemically pure it is colourless. It fumes strongly in the air, emitting a corrosive vapour of a peculiar smell. The characteristic test of muriatic acid in the most dilute state, is nitrate of silver, which causes a curdy precipitate of chloride of silver.

The preparation of this acid upon the great scale is frequently effected in this country by acting upon sea-salt in hemispherical iron pots, or in cast-iron cylinders, with concentrated sulphuric acid; taking 6 parts of the salt to 5 of the acid. The mouth of the pot may be covered with a slab of siliceous freestone, perforated with two holes of about two inches in diameter each, into the one of which the acid is poured by a funnel in successive portions, and into the other, a bent glass, or stone-ware tube, is fixed, for conducting the disengaged muriatic gas into a series of large globes of bottle glass, one-third filled with water, and laid on a sloping sand-bed. A week is commonly employed for working off each pot; no heat being applied to it till the second day.

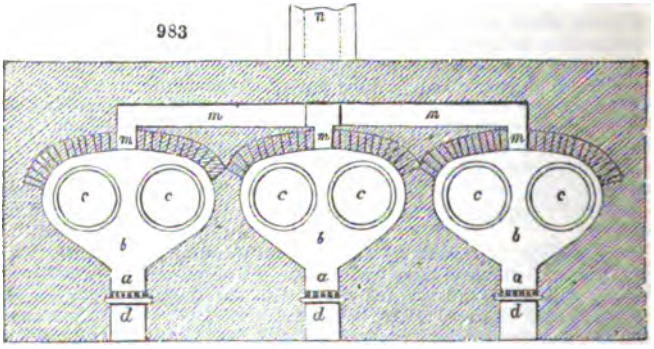
The decomposition of sea-salt by sulphuric acid was at one time carried on by some French manufacturers in large leaden pans, 10 feet long, 5 feet broad, and a foot deep, covered with sheets of leads, and luted. The disengaged acid gas was made to circulate in a conduit of glazed bricks, nearly 650 yards long, where it was condensed by a sheet of water exceedingly thin, which flowed slowly in the opposite direction of the gas down a slope of 1 in 200. At the end of this canal nearest the apparatus, the muriatic acid was as strong as possible, and pretty pure; but towards the other end, the water was hardly acidulous. The condensing part of this apparatus was therefore

tolerably complete; but as the decomposition of the salt could not be finished in the leaden pans, the acid mixture had to be drawn out of them, in order to be completely decomposed in a reverberatory furnace; in this way nearly 50 per cent. of the muriatic acid was lost. And besides, the great quantity of gas given off during the emptying of the lead-chambers was apt to suffocate the workmen, or seriously injured their lungs, causing severe hemoptysis. The employment of muriatic acid is so inconsiderable, and the loss of it incurred in the preceding process is of so little consequence, that subsequently, both in France and in England, sulphate of soda, for the soda manufacture, has been procured with the dissipation of the muriatic acid in the air. In the method more lately resorted to, the gaseous products are discharged into extensive vaults, where currents of water condense them and carry them off into the river. The surrounding vegetation is thereby saved in some measure from being burned up, an accident which was previously sure to happen when fogs precipitated the floating gases upon the ground. At Newcastle, Liverpool, and Marseilles, where the consumption of muriatic acid bears no proportion to the manufacture of soda, this process is now practised upon a vast scale.

The apparatus for condensing muriatic acid gas has been modified and changed, of late years, in many different ways.

The Bastringue apparatus. At the end of a reverberatory furnace, rectangular lead trough or pan, about 1 foot deep, of a width equal to that of the interior of the furnace, that is, about 5 feet wide, and 6½ feet long, is encased in masonry, having its upper edges covered with cast-iron plates or fire tiles, and placed upon a level with the passage of the flame, as it escapes from the reverberatory. The arch which covers that pan forms a continuation of the roof of the reverberatory, and is of the same height. The flame which proceeds from the furnace containing the mixture of salt and sulphuric acid is made to escape between the vault and the surface of the iron plates or fire tiles, through a passage only 4 inches in height. When the burned air and vapours reach the extremity of the pan, they are reflected downwards, and made to return beneath the bottom of the pan, in a flue, which is afterwards divided so as to lead the smoke into two lateral flues, which terminate in the chimney. The pan is thus surrounded as it were with the heat and flame discharged from the reverberatory furnace. A door is opened near the end of the pan, for introducing the charge of sea-salt, amounting to 12 bags of 2 cwt. each, or 24 cwt. This door is then luted on as tightly as possible, and for every 100 parts of salt, 110 of sulphuric acid are poured in, of specific gravity 1·594, containing 57 per cent. of dry acid. This acid is introduced through a funnel inserted in the roof of the furnace. Decomposition ensues, muriatic acid gas mingled with steam is disengaged, and is conducted through 4 stone-ware tubes into the refrigerators, where it is finally condensed. These refrigerators consist of large stone-ware carboys, called *dame-jeannes* in France, to the number of 7 or 8 for each pipe, and arranged so that the neck of the one communicates with the body of the other; thus the gas must traverse the whole series, and gets in a good measure condensed by the water in them, before reaching the last.

When the operation is finished, the door opposite the pan is opened, and the residuum in it is discharged, in the form of a fluid magma, upon a square bed of bricks, exterior to the furnace. This paste speedily concretes on cooling, and is then broken into fragments and carried to the soda manufactory. The immense quantity of gas exhaled in discharging the pan, renders this part of the operation very painful



to the workmen, and wasteful in reference to the production of muriatic acid. The difficulty of luting securely the cast-iron plates or fire tiles which cover the pan, the

impossibility of completing the decomposition of the salt, since the residuum must be run off in a liquid state, finally, the damage sustained by the melting and corrosion of the lead, &c., are among the causes why no more than 80 or 90 parts of muriatic acid at 1·170 are collected, equivalent to 25 per cent. of real acid for every 100 of salt employed, instead of much more than double that quantity, which it may be made to yield by a well conducted chemical process.

The *cylinder apparatus* is now much esteemed by many manufacturers. *Fig.* 983 represents, in transverse section, a bench of iron cylinder retorts, as built up in a proper furnace for producing muriatic acid; and *fig.* 984 a longitudinal section of one retort with one of its carboys of condensation. *a* is the grate; *b*, a fireplace, in which two iron cylinders, *c c*, are set alongside of each other. They are 5½ feet long, 20 inches in diameter, about ¼ of an inch thick, and take 1·6 cwt. of salt for a charge; *d* is the ashpit; *e e* are cast-iron lids for closing both ends of the cylinders; *f* is a tube in the posterior lid, for pouring in the sulphuric acid; *g* is another tube, in the anterior lid, for the insertion of the bent pipe of hard glazed stoneware *h*; *i* is a three-necked stone-ware carboy; *k* is a tube of safety; *l*, a tube of communication with the second carboy; *m m m m* are the flues leading to the chimney *n*.

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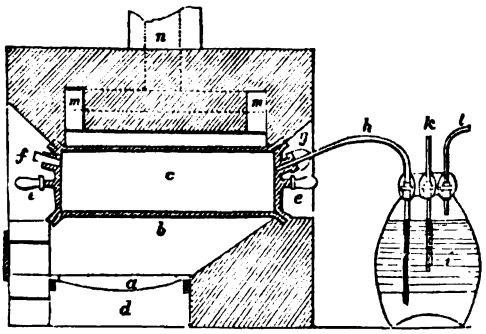


After the salt has been introduced, and the fire kindled, 83½ per cent. of its weight of sulphuric acid, of sp. gr. 1·80, should be slowly poured into the cylinder through a lead funnel, with a siphon-formed pipe. The three-necked carboys may be either placed in a series for each retort, like a range of Woulfe's bottles, or all the carboys of the front range may be placed in communication with one another, while the last carboy at one end is joined to the first of the second range; and thus in succession. They must be half filled with cold water; and when convenient, those of the front row at least, should be plunged in an oblong trough of running water. The acid which condenses in the carboys of that row is apt to be somewhat contaminated with sulphuric acid, muriate of iron, or even sulphate of soda; but that in the second and third will be found to be pure. In this way 100 parts of sea-salt will yield 130 parts of muriatic acid, of sp. gr. 1·19; while the sulphate of soda in the retort will afford from 208 to 210 of that salt in crystals.

It is proper to heat all the parts of the cylinders equally, to insure the simultaneous decomposition of the salt, and to protect it from the acid; for the hotter the iron, and the stronger the acid, the less erosion ensues.

Some manufacturers, with the view of saving fuel by the construction of their furnaces, oppose to the flame as many obstacles as they can, and make it perform numerous circulations round the cylinders; but this system is bad, and does not even effect the desired economy, because the passages, being narrow, impair the draft, and become speedily choked up with the soot, which would be burned profitably in a freer space; the decomposition also, being unequally performed, is less perfect, and the cylinders are more injured. It is better to make the flame envelope at once the body of the cylinder; after which it may circulate beneath the vault, in order to give out a portion of its caloric before it escapes at the chimney.

The fire should be briskly kindled, but lowered as soon as the distillation commences; and then continued moderate till the evolution of gas diminishes, when it must be heated somewhat strongly to finish the decomposition. The iron door is now removed, to extract the sulphate of soda, and to recommence another operation. This sulphate ought to be white and uniform, exhibiting in its fracture no undecomposed sea-salt.

Liquid muriatic acid has a very sour corrosive taste, a pungent suffocating smell, and acts very powerfully upon a vast number of mineral, vegetable, and animal substances. It is much employed for making many metallic solutions; and in combination with nitric acid, it forms the aqua regia of the alchemists, so called from its property of dissolving gold. See SODA MANUFACTURE.

Table of Hydrochloric Acid, by Dr. Ure.

Acid of 120 in 100.	Specific Gravity.	Chlorine.	Muriatic Gas.	Acid of 120 in 100.	Specific Gravity.	Chlorine.	Muriatic Gas.	Acid of 120 in 100.	Specific Gravity.	Chlorine.	Muriatic Gas.
100	1·2000	39·675	40·777	66	1·1328	26·186	26·913	32	1·0637	12·697	13049
99	1·1982	39·278	40·369	65	1·1308	25·789	26·505	31	1·0617	12·300	12·641
98	1·1964	38·882	39·961	64	1·1287	25·392	26·098	30	1·0597	11·903	12·233
97	1·1946	38·485	39·554	63	1·1267	24·996	25·690	29	1·0577	11·506	11·825
96	1·1928	38 089	39·146	62	1·1247	24·599	25·282	28	1·0557	11·109	11 418
95	1·1910	37·692	38·738	61	1·1226	24·202	24·874	27	1·0537	10·712	11·010
94	1·1893	37·296	38·330	60	1·1206	23·805	24·466	26	1·0517	10·316	10·602
93	1·1875	36·900	37·923	59	1·1185	23·408	24 058	25	1·0497	9·919	10·194
92	1·1857	36·503	37·516	58	1·1164	23·012	23·050	24	1·0477	9·522	9·786
91	1·1846	36·107	37·108	57	1·1143	22·615	23·242	23	1·0457	9·125	9·379
90	1·1822	35·707	36 700	56	1·1123	22·218	22·834	22	1·0437	8·729	9·971
89	1·1802	35·310	36·292	55	1·1102	21·822	22·426	21	1·0417	8·332	8·563
88	1 1782	34·913	35·884	54	1·1082	21·425	22·019	20	1·0397	7·935	8·155
87	1·1762	34·517	35·476	53	1·1061	21·028	21·611	19	1·0377	7·538	7·747
86	1·1741	34·121	35·068	52	1·1041	20·632	21·203	18	1·0357	7·141	7·340
85	1·1721	33·724	34·660	51	1·1020	20·235	20·796	17	1·0337	6·745	7·932
84	1·1701	33·328	34·252	50	1·1000	19·837	20·388	16	1·0318	6·348	6·524
83	1·1681	32·931	33·845	49	1·0980	19·440	19·980	15	1·0298	5·951	6·116
82	1·1661	32·535	33·437	48	1·0960	19·044	19·572	14	1·0279	5·554	6·709
81	1·1641	32·136	33·029	47	1·0939	18·647	19·165	13	1·0259	5·158	5·301
80	1·1620	31·746	32·621	46	1·0919	18·250	18·757	12	1·0239	4·762	5·893
79	1·1599	31·343	32·213	45	1·0899	17·854	18·359	11	1·0220	4·365	4·486
78	1·1578	30·946	31·805	44	1·0879	17·457	17·941	10	1·0200	3·968	4 078
77	1·1557	30·550	31·398	43	1·0859	17·060	17·534	9	1·0180	3·571	4·670
76	1·1536	30·153	30·990	42	1 0838	16·664	17·126	8	1·0160	3·174	3·262
75	1·1515	29·757	30·582	41	1·0818	16·267	16·718	7	1·0140	2·778	3·854
74	1·1494	29·361	30·174	40	1·0798	15·870	16·310	6	1·0120	2·381	3·447
73	1·1473	28·964	39·767	39	1·0778	15 474	15·902	5	1·0100	1·984	2·039
72	1·1452	28·567	29·359	38	1·0758	15·077	15·494	4	1·0080	1·588	2·631
71	1 1431	28·171	28·951	37	1·0738	14·680	15·087	3	1·0060	1·191	1·224
70	1·1410	27·772	28·544	36	1·0718	14·284	14·679	2	1·0040	0·795	1·816
69	1·1389	27·376	28·136	35	1·0697	13·887	14·271	1	1·0020	0·397	1·408
68	1 1369	26·979	27·728	34	1·0677	13·490	13·863				
67	1·1349	26·583	27·321	33	1·0657	13·094	13·456				

HYDROCYANIC ACID. Syn. *Cyanhydric acid, Prussic acid,* C^2NH. This highly important acid is regarded by all chemists as being formed on the exact type of the ordinary inorganic hydracids, such as the hydrochloric or hydriodic. The compound radical analogous to chlorine, which is contained in it, has received the name of cyanogen, and possesses the formula C^2N. That this body is precisely analogous in its relations to the simple salt radicals is rendered certain by numerous facts. It combines directly with metals to form compounds; it possesses the same vapour volume, and unites with hydrogen to form a hydracid, which in its turn decomposes the metallic oxides with formation of water. Thus we have, with metallic oxides and hydrochloric acid (M standing for a metal), $MO + HCl = MCl + HO$, and with hydrocyanic and metallic oxides (Cy standing for cyanogen), $MO + HCy = MCy + HO$. Two volumes of chlorine and two of hydrogen yield four volumes of hydrochloric acid gas, and two volumes of cyanogen with two of hydrogen yield four volumes of hydrocyanic acid. The density of the vapour of hydrocyanic acid is consequently 0·9476. The theoretical number being 0·9342. Its density in the fluid state is 0·6967 at a temperature of 64·4°. It boils at 80° F. at ordinary pressures.

Hydrocyanic acid is never prepared in the anhydrous state except as a curiosity or for the purpose of scientific investigation. In fact it cannot be long preserved of great strength; a somewhat complex decomposition invariably taking place in it, with production of brown adhesive matters containing cyanide of ammonium, and also a substance by some considered to be an acid, and known as the azulmic. Paracyanogen is probably formed at the same time. The constitution of azulmic acid is by no means well known, and even its very existence, as a definite chemical substance, is doubtful. It is singular that the presence of a mineral acid greatly retards the decomposition of prussic acid, especially if it be dilute; the pharmacopœian acid consequently may be preserved of uniform strength, in well filled and closely stoppered

bottles, for almost any length of time. The deadly nature of prussic acid unhappily causes it to be only too frequently resorted to by the despairing or the murderer. Fortunately, however, in spite of its volatility, the chemist possesses excellent means for its detection.

Preparation.—1. Hydrated acid. As prussic acid is largely employed in medicine, but in a very dilute form, it is usual to prepare it and dilute until of the proper degree of strength. The following process for preparing it will be found to give a satisfactory result, and, moreover, it may be performed on any quantity of materials. The apparatus for the purpose will vary with the scale on which the experiment is to be made. If on a few ounces, glass retorts and flasks answer well, if good condensation is ensured, by means of a Liebig's condenser well supplied with very cold water. If a large quantity of prussic acid is to be made, such as several gallons, the apparatus should consist of a stoneware still, with head adjusted by grinding. The head should be capable of adjustment with a stoneware adapter to a worm of the same material enclosed in a tub of water. The joints are to be luted with a mixture of one handful of almond meal and five handfuls of linseed meal, worked with water to the consistence of putty. A solution of rough chloride of calcium in water is to be made and placed in a large iron pot, with a cover so contrived as to permit the still to drop in up to the flange. 10 parts of yellow prussiate of potash are then to be bruised in a mortar and mixed with dilute sulphuric acid prepared by adding 6 parts of sulphuric acid (density 1·850) to 42 of water. The head being luted on, a fire is to be kindled in the furnace under the iron pot, and the chloride of calcium bath is to be kept boiling constantly until 36 parts of acid have distilled over. The beak of the still should be placed in the funnel which conducts the acid to the Winchester quart bottles which are to contain the product, and a piece of wet bladder is to be stretched over the funnel to prevent evaporation of the acid into the laboratory. The worm used for the purpose must be ascertained to be perfectly clean, and, if prussic acid is to be frequently made, should be kept specially for that operation. To each Winchester quart of the acid distilling over, one drop of sulphuric acid may be added to insure its keeping. But the acid thus prepared generally keeps for a long time even without this precaution, owing probably to small traces of the sulphuric acid being carried over during the distillation.

It is quite impossible to conduct the operation so as to yield a product of uniform strength; it is absolutely necessary, therefore, to determine the percentage of real hydrocyanic acid, and dilute it to the required degree. It fortunately happens that 1 grain of hydrocyanic acid yields almost exactly 5 grains of cyanide of silver; for one equivalent of acid = 27 produces 1 equivalent of cyanide of silver = 134; so that 27 : 134 :: 1 : 4·96. The acid produced will have, probably, to be reduced to one of two standards; namely, the so-called Scheele's strength, containing 5 per cent. of acid, or the P.L., containing 2 per cent.; 100 grains of the former should, consequently, yield 25 grains, and 100 of the P.L. 10 grains of cyanide of silver. In either case the calculation becomes obvious.

2. The anhydrous acid. Several processes for conducting this dangerous operation are known; the following is, perhaps, the most generally convenient. A large glass retort is so arranged that its neck is directed upwards at an angle of about 45°; a cork fitted to the aperture in the neck connects a glass tube with a bottle containing a little chloride of calcium. From the latter vessel another tube proceeds to a U tube containing fragments of chloride of calcium, and from the latter a third, conducting the dehydrated vapour of prussic acid to an upright glass tube contained in a mixture of ice and salt. Into the retort is placed a mixture of 10 parts of yellow prussiate of potash, 7 of oil of vitriol, and 14 of water. The retort is to be heated with a charcoal fire, and the temperature of the bottle and U tube, containing the chloride of calcium, is not to be allowed to fall below 90°, in order to prevent condensation of the anhydrous prussic acid taking place anywhere except in the tube contained in the freezing mixture. The vapour of anhydrous prussic acid is so dangerous that the greatest precaution must be taken to prevent inhaling the smallest portion.

Detection of prussic acid.—When prussic acid exists in moderate quantity in a solution it may be detected by first adding a few drops of potash, then a mixture of protosulphate and persulphate of iron, and finally a little hydrochloric acid; a bright blue precipitate indicates the presence of the acid. A much more delicate test, and one that is applicable when, from the dilution of the solution, the salts of iron are no longer capable of acting, is by the conversion of the prussic acid into sulphocyanide of ammonium. For this purpose the prussic acid is to be warmed on a watch glass with a drop of sulphide of ammonium, until the solution has become colourless. The addition of a trace of a solution of a persalt of iron will show, by the formation of a blood red colour, the presence of the acid sought. A very neat mode of applying this test is to place one drop of sulphide of ammonium on a watch glass inverted over

another containing the suspected fluid. On leaving the apparatus in a warm place, arranged in this manner, for a short time, the upper glass will be found to contain sulphocyanide of ammonium, which, after drying, will be in a state well adapted for showing the reaction with a persalt of iron.—C. G. W.

HYDRODYNAMICS. The mechanical science which treats of the motion of fluids. This science has, of course, most important bearings on the pumping-engines, water-wheels, &c., employed to facilitate the operation of the miner. It is not however possible to embrace this, which belongs to mechanical engineering, in this work.

HYDRO-EXTRACTOR. A name sometimes given to the machines employed for expelling the water from woven goods. See DESICCATION.

HYDROFLUORIC ACID. It was observed by Scwankhardt, in 1670, that fluor spar and oil of vitriol would eat into glass. Scheele, in 1771, determined that this peculiar property was due to the liberation of an acid from the fluor spar.

Hydrofluoric acid is best obtained by placing finely powdered fluor spar in a leaden retort, and twice its weight of highly concentrated oil of vitriol. By a gentle heat the gas is distilled over, which must be collected in a leaden tube, in which, by means of a freezing mixture, it may be condensed into a liquid. If a solution of this acid in water is required, the extremity of the tube from the retort is carried into a vessel of water.

Hydrofluoric acid attacks glass with great readiness, by acting on its silica.

Glass upon which any design is to be etched, is covered with an etching wax, and the design made in the usual manner; this is placed over a leaden vessel, in which is a mixture of fluor spar and oil of vitriol; a gentle heat being applied, hydrofluoric acid escapes, and immediately attacks the glass. See FLUORINE.

HYDROGEN. (Eng. and Fr.; *Wasserstoff*, Germ.) A permanently gaseous, elementary body, the lightest of all known substances, its specific gravity being ·0693; 100 cubic inches weighing, under ordinary pressure and temperature, only 2·14 grains. It is therefore nearly 14·5 times lighter than atmospheric air.

From its extreme lightness it was formerly used for filling balloons, but has been superseded for that purpose by ordinary coal gas, which can be obtained at a much cheaper rate: the difference of buoyant power being compensated by increasing considerably the size of the balloon. It is itself inflammable, but not a supporter of combustion, its combination with oxygen forming water, which contains $\frac{1}{9}$th of its weight of hydrogen.

It is generally prepared by the action of dilute sulphuric acid on zinc, although there are many other processes which furnish it; as the decomposition of steam by iron filings with the aid of heat, &c.

In the act of combining with oxygen, as when burnt in the oxyhydrogen blowpipe, the greatest possible heat is obtained; a piece of stout platinum wire being fused when placed in the flame, which cannot be effected by the greatest heat attained in our furnaces.

Hydrogen is sometimes used for soldering metals; in which process it is requisite to bring the two surfaces of the metal together in a perfectly metallic state at a high temperature. Hydrogen effects this completely; by its combustion it supplies the heat, and by entering into combination with the oxygen of the air, prevents the formation of oxides, which are so easily formed at the temperature required for the melting of the metals, and which, when present, prevent the union of the surfaces. See AUTOGENOUS SOLDERING.

Hydrogen is often used also for the reduction of metals from their different combinations; the reduction is effected by passing a current of hydrogen over the compounds heated to redness.

Its use in reducing ores on the large scale has been proposed, but as yet not found practicable.—H. K. B.

HYDROMETER. An instrument for ascertaining the specific gravities of liquids. Baumé's hydrometer, which is much used in France, and other countries of the continent of Europe, when plunged in pure water, at the temperature of 58° Fahr., marks 0 upon its scale; in a solution containing 15 per cent. of common salt (chloride of sodium), and 85 of water by weight, it marks 15°; so that each degree is meant to indicate a density corresponding to one per cent. of that salt. See ALCOHOLMETRY and AREOMETER.

HYDROPHANE. A variety of opal which readily imbibes water, and when immersed it becomes transparent, though opaque when dry. It is found in Hungary, and in Ireland, near the Giant's Causeway, and at Crosreagh, Ballywillin.

HYDROSTATICS. The science which treats of the equilibrium of fluids, and of the pressure exerted by them.

In the engineering arrangements by which water is supplied to towns, hydrostatics becomes of the utmost importance. The highest possible level is obtained for the

reservoir; and from this a series of pipes is arranged through all the streets and houses. The tendency of the water is to rise to its original level, and hence all the pipes are filled with water, and in all such as are below the level of the water in the reservoir a pressure upward is exerted equal to the height of the reservoir above that point; and if a hole is pierced in the pipe, the water jets out with a force equal to this pressure. In the highest houses, the water perhaps only finds its level, and flows out without pressure quickly. See WATER PRESSURE ENGINES; HYDRAULIC CRANE.

HYDROSULPHURETS. Chemical compounds of bases with sulphuretted hydrogen, or hydrosalphuric acid.

HYMENŒA COURBARIL. A tree growing in South America, from which the resin *animé* exudes.

HYPEROXYMURIATES. The old and incorrect name of CHLORATES.

HYPOCHLORIC ACID. ClO^4. Eq. 67·5. When finely powered chlorate of potash is gradually mixed into a paste with strong sulphuric acid, and heated in a bath of alcohol and water, a yellow gas is disengaged which is this hypochloric acid, or the *peroxide of chlorine*. Although of much interest as a chemical compound, it has no use in the arts. See *Ure's Chemical Dictionary*.

HYPOCHLOROUS ACID. ClO. Eq. 43·5. This acid is best obtained by diffusing red oxide of mercury finely divided through twelve times its weight of water, which is introduced into a bottle containing chlorine, and agitated until the gas is absorbed. An oxychloride of mercury is formed, which is removed by subsidence. The weak fluid obtained is put into a flask, and heated in a water bath, when the evolved gas is collected in a smaller portion of water, which becomes a pure solution of hypochlorous acid.

The salts are termed hypochlorites. See CHLORINE and BLEACHING.

HYPOSULPHATES. Saline compounds formed by the union of hyposulphuric acid with bases.

HYPOSULPHITES. Saline compounds formed by the union of hyposulphurous acid with bases.

Hyposulphate of Soda. The salts of the hyposulphuric acid are obtained from the hyposulphate of manganese, which is itself thus prepared: finely divided binoxide of manganese is suspended in water, artificially cooled, and a stream of sulphurous acid passed through it. The binoxide gives up half its oxygen, becoming protoxide, which unites with the hyposulphuric acid which is formed, producing the soluble hyposulphate of manganese, which is separated from the excess of binoxide by filtration.

The following equation represents the reaction:—

$$MnO^2 + 2SO^2 = MnO,S^2O^5.$$

If the temperature were allowed to rise, sulphuric acid would be formed, and not hyposulphuric:—

$$MnO^2 + SO^2 = MnO,SO^3.$$

The hyposulphuric acid, unlike the hyposulphurous acid, may be obtained in the free state, and its solution permits even of being evaporated *in vacuo*, until it acquires the density of 1·347; but if carried further, it is decomposed into sulphuric and sulphurous acids.

The acid is obtained in the free state by adding baryta water to the hyposulphate of manganese; the soluble hyposulphate of baryta, filtered from the oxide of manganese, and precipitated exactly by the cautious addition of sulphuric acid, and filtered from the precipitate of sulphate of baryta, yields the pure solution of the acid, which may be evaporated *in vacuo*, as above stated.

It has no odour, but a very sour taste.

The hyposulphate of soda may be made directly from the manganese salt or from the free acid.

All the hyposulphates are soluble; they have not as yet met with any commercial application.

Hyposulphite of Soda. This salt, now so extensively used for photographic purposes, was first introduced by Sir J. Herschel. It may easily be prepared by the following process: viz. by transmitting through a solution of sulphide of sodium (prepared by fusing together in a covered crucible equal weights of carbonate of soda, and flowers of sulphur), a stream of sulphurous acid until it ceases to be absorbed; the liquid is then filtered and evaporated, when the hyposulphite of soda ($NaO,S^2O^2 + 5HO$) crystallises out.

Another and perhaps better process consists in digesting a solution of sulphite of soda on flowers of sulphur. The sulphur gradually dissolves, forming a colourless

solution, which yields on evaporation crystals of hyposulphite of soda; the reaction being shown by the following equation: —

$$NaO,SO^2 + S = NaO,S^2O^2.$$

The baryta salt may be obtained in small brilliant crystals, by mixing dilute solutions of chloride of barium and hyposulphite of soda.

The hyposulphurous acid is incapable of existing in the free state, for almost immediately on the addition of an acid to the solution of its salts, it is decomposed into sulphurous acid, with liberation of sulphur. ($S^2O^2 = SO^2 + S$.)

The soluble hyposulphites have the power, in a marked degree, of dissolving certain salts of silver, as the chloride, iodide, &c., which are insoluble in water; forming with them soluble salts, whose solutions possess an intensely sweet taste, although the solutions of the hyposulphites alone possess a disagreeable bitter taste.

From the above reaction arises the principal value of the hyposulphite of soda, which is used by the photographer to dissolve off from the photograph, after the action of the light on it, all the undecomposed silver salt, thus preventing the further action of the light on the picture.

A double hyposulphite of soda and gold is used for gilding the daguerreotype plate, and for colouring the positive proof obtained in photographic printing. This double salt may be obtained in a state of purity, by mixing concentrated solutions of 1 part of chloride of gold, and 3 parts of hyposulphite of soda; by the addition of alcohol it is precipitated; the precipitate must be re-dissolved in a small quantity of water, and again precipitated by alcohol. Its formation is explained by the following equation: —

$$8(NaO,S^2O^2) + AuCl^3 = \underbrace{2(NaO,S^4O^5)}_{\text{Tetrathionate of soda.}} + \underbrace{AuO,S^2O^2,3(NaO,S^2O^2)}_{\text{Hyposulphite of soda and gold.}} + \underbrace{3NaCl}_{\text{Chlor. of sodium.}}$$

H. K. B.

HYSON. A green tea. See TEA.

I.

IBEX. An animal of the goat kind, the hair of which is esteemed for some kinds of manufacture.

ICEHOUSE. (*Glacière*, Fr.; *Eishaus*, Germ.) Under the article FREEZING, the different artificial methods of producing cold are enumerated. But for the uses of common life, in these climates, the most economical and convenient means of refrigeration in hot weather may be procured by laying up a store of ice in winter, in such circumstances as will preserve it solid during summer.

An icehouse should not be regarded as an object of mere luxury; in the southern countries of Europe it is considered among people in easy circumstances as an indispensableappendage to a country mansion. During the dog days, especially at those periods and in those districts where the *sirocco* blows, a lassitude and torpor of mind and body supervene, with indigestion or total loss of appetite, and sometimes dysenteries, which are obviously occasioned by the excess of heat, and are to be prevented or counteracted chiefly by the use of cold beverages. By giving tone to the stomach, iced drinks immediately restore the functions of the nervous and muscular systems when they are languid; while they enable persons in health to endure without much inconvenience an atmosphere so close and sultry as would be intolerable without this remedy. Icehouses, moreover, afford to country gentlemen a great advantage in enabling them to preserve their fish, butcher meat, dead poultry, and game, which would otherwise, in particular states of the weather, immediately spoil. Considering at how little expense and trouble an icehouse can be constructed, it is surprising that any respectable habitation in the country should not have one attached to it. The simplest and most scientific form is a double cone, that is, two cones joined base to base; the one being of stones or brick-work, sunk under ground, with its apex at the bottom, into which the ice is rammed; the other being a conical roof of carpentry covered with thatch, and pointed at top. The entrance should be placed always on the north side; it should consist of a corridor or porch with double doors, and be screened from the sunbeams by a small shrubbery. Such are the principles upon which an icehouse should be formed; but they will be better understood by the following explanation and figure.

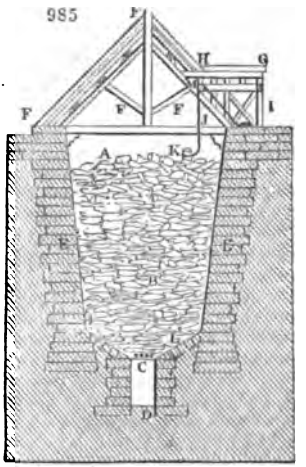
A dry and sandy soil if possible should be selected; and here a cavity is to be dug about 16 feet in diameter, terminating below like the point of a sugar loaf. Its

ordinary depth for a family may be about 24 feet; but the larger its dimensions are, the longer will it preserve the ice, provided it be filled. In digging, the workman should slope the ground progressively towards the axis of the cone, to prevent the earth falling in. This conical slope should be faced with brick or stone work about one foot thick, and jointed with Roman cement, so as to be air and water-tight. A well is to be excavated, at the bottom 2 feet wide and 4 deep, covered at top with an iron grating for supporting the ice, and letting the water drain away.

The upper cone may likewise be built of brick-work, and covered with thatch; such a roof would prove the most durable. This is the construction shown in *fig.* 984. Whatever kind of roof be preferred, there must be left in it an oblong passage into the interior. This porch should face the north, and be at least 8 feet long by 2½ feet wide; and perfectly closed by a well-fitted door at each end. All round the bottom of this conical cover, a gutter should be placed to carry off the rain to a distance from the icehouse, and prevent the circumjacent ground from getting soaked with moisture.

Fig. 985 shows the section of a well-constructed icehouse. Under the ice chamber A the ice is rammed into the space B. C is the grate of the drain sink D. The portion E E is built in brick or stone; the base L of the ice-chamber slopes inwards towards the centre at C. The upper part of the brick-work E E is a little way below the level of the ground. The wooden framework F F F F forms the roof, and is covered with thick thatch. G H is the wooden work of the door I. At K the bucket is seen for lifting up a charge of ice, by means of the cord J passing over the pulley M, which enables the servant to raise it easily.

985



The icehouse should have no window to admit light; but be, so to speak, hermetically sealed in every point, except at its cesspool, which may terminate in a water trap to prevent circulation of air.

A clear day should be selected for charging the icehouse; but before beginning to fill, a quantity of long dry straw should be laid on the bottom crosswise; and as the ice is progressively introduced, straw is to be spread against the conical sides, to prevent the ice from coming into contact with the brick or stone-work. The more firmly compacted the ice is, the better does it keep; with which view it should be broken into pieces with mallets before being thrown in. No layers of straw should be stratified among the ice, for they would make its body porous. Some persons recommend to pour in a little water with the successive layers of ice, in order to fill up its small crevices, and convert the whole into one mass.

Over the top layer a thick bed of straw should be spread, which is to be covered with boards surmounted with heavy stones, to close up the interstices in the straw. The inner and outer door should never be opened at once; but the one should always be shut before the other is opened.

Dry snow well rammed keeps equally well with hard ice, if care be taken to leave no cavities in the mass, and to secure its compactness by sprinkling a little water upon the successive charges.

To facilitate the extraction of the ice, a ladder is set up against its sloping wall at one side of the door, and left there during the season.

ICE BY THE RED-HOT PROCESS. See SPHEROIDAL STATE.

ICE-PRODUCING MACHINE. See FREEZING.

ICELAND MOSS (*Lichen d'Islande*, Fr.; *Flechte Isl.*, Germ.) is a lichen, the *Cetraria Islandica*, which contains a substance soluble in hot water, but forming a jelly when it cools, styled *lichenine* by M. Guerin. This moss is called in the Pharmacopiæ *Lichen Islandicus*. It appears to have derived its name from the circumstance that the Icelanders first discovered its medicinal qualities. Lichenine is prepared by extracting first of all from the plant a bitter colouring matter, by digesting 1 pound of it in 16 pounds of cold water containing one ounce of pearl-ash; then draining the lichen, edulcorating with cold water, and boiling it in 9 pounds of boiling water, till 3 pounds be evaporated. The jelly which forms, upon cooling the filtered solution, is dark coloured, but, being dried and redissolved in hot water, it becomes clear and colourless. Lichenine consists of 39·33 carbon, 7·24 hydrogen, and 55·43 oxygen. The mucilage of Iceland moss is preferred in Germany to common paste for dressing

the warp of webs in the loom, because it remains soft, from its hygrometric quality. It is also mixed with the pulp for sizing paper in the vat. For several curious compounds obtained from Iceland moss, see *Ure's Chemical Dictionary*.

ICELAND SPAR. Crystallised carbonate of lime, of which the most beautiful specimens are brought from Iceland. These are remarkable for their double refraction; and hence this crystal is sometimes called *double refracting spar*.

IDWALE-STONE. A peculiar Welsh hone stone. It is obtained from the older slate rocks of the Snowdon district.

ILIXANTHINE. A substance which might be employed for dyeing yellow, derived from the leaves of the common holly.

ILLUMINATION. *The means of determining the relative values of various sources of illuminating power.*

It is often of the utmost importance that we should be enabled, with facility, to determine the relative values of the light which we obtain from artificial sources. The only way in which this can be effected, is by comparing with some standard source of light the illuminating sources employed. Dr. Ure, who was on several occasions called on to direct his attention to inquiries of this nature, instituted many very ingenious and exact experiments; to some of these it appears important that we should direct especial attention. Of the original paper on the cost of illumination, many parts are now obsolete; but as much of it is still of considerable practical value, the following selections have been made, all such being distinguished by Dr. Ure's name. After many experiments to determine a standard, Dr. Ure says:—

"After comparing lights of many kinds, I find every reason to conclude that a large wax candle of three to the pound, either long or short, that is, either 12 or 15 inches in length, as manufactured by one of the great wax-chandlers of London, and furnished with a wick containing 27 or 28 threads of the best Turkey cotton, is capable of furnishing a most uniform, or nearly invariable standard of illumination. It affords one-tenth of the light emitted by one of the Argand lamps of the Trinity House, and one-eleventh of the light of my mechanical lamp, when each lamp is made to burn with its maximum flame, short of smoking."

Dr. Ure, however, for many of his determinations employed the French mechanical lamp, known as Carcel's lamp; and in connexion with this the following remarks occur:—

"Mr. Samuel Parker, long advantageously known to the public for his sinumbral and pneumatic fountain lamps, as well as other inventions subservient to domestic comfort, having obtained a patent for a new lamp, in which the oil is heated by a very simple contrivance, in the cistern, to any desired degree, before arriving at the wick, I instituted an extensive series of experiments to determine its value in the production of light, and consumption of oil, compared to the value of other lamps, as well as candles, in these respects.

In *fig.* 986 A, A, B, B, is a section of the cylinder which constitutes the cistern; the oil being contained between the inner and outer cylinders, and receiving heat from the flame of the lamp which passes up through the inner cylinder, and is reverberated more or less against its sides by the top of the metal chimney being notched and bent back. D is a slide-valve, which is opened to allow the oil to descend to the wick, and is shut when the cistern is to be separated from the pipe of supply, at E, for the purpose of recharging it with oil. The flame is modified, not by raising or lowering the wick, as in common lamps, but by raising or lowering the bell-mouthed glass chimney which rests at its bottom on three points, and is moved by means of the rack-work mechanism F. The concentric cylindric space A, A, and B, B, contains a pint imperial, and should be made entirely full before lighting the lamp; so as to leave no air in the cistern, which, by its expansion with the heat, would inevitably cause an overflow of the oil.

The following arrangement was adopted in these experiments for determining the relative illumination of the different lights. Having trimmed, with every precaution, my French mechanical lamp, and charged it with pure sperm oil, I placed it upon an oblong table, at a distance of 10 feet from a wall, on which a white sheet of paper was stuck. One of Mr. Parker's Rot-oil lamps, charged with a quantity of the same oil, was placed upon the same table; and each being made to burn with its maximum brilliancy, short of smoking, the relative illumination of the two lamps was determined by the well-known method of the comparison of shadows; a wire a few inches long, and of the thickness of a crow-quill, being found suitable for enabling the eye to estimate very nicely the shade of the intercepted light. It was observed in numerous trials, both by my own eyes and those of others, that when one of the lamps was shifted half an inch nearer to or further from the paper screen, it caused a perceptible difference in the tint of the shadow. Professor Wheatstone kindly enabled me to verify the precision of the above method of shadows, by employing, in some of the experi-

ments, a photometer of his own invention, in which the relative brightness of the two lights was determined by the relative brightness of the opposite sides of a revolving silvered ball, illuminated by them.

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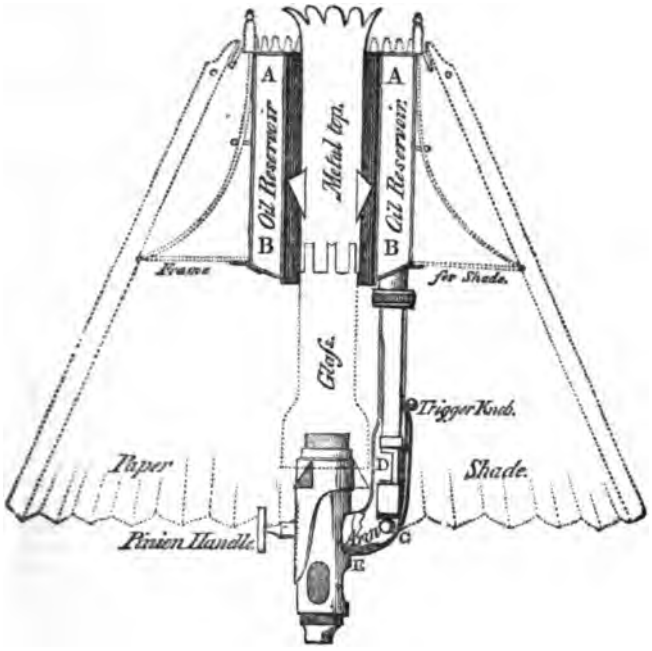

1. The mechanical lamp was furnished with a glass chimney 1·5 inch in diameter at the base, and 1·2 at top; the wide bottom part was 1·8 inch long, and the narrow upper part 8 inches. When placed at a distance of 10 feet from the wall its light there may be estimated as the square of this number, or 100. In the first series of experiments, when burning with its maximum flame, with occasional flickerings of smoke, it emitted a light equal to that of 11 wax candles, and consumed 912 grains of oil per hour. The sperm oil was quite pure, having a specific gravity of 0·874 compared to water at 1000. In a subsequent series of experiments, when its light was less flickering, and equal only to that of 10 wax candles, it consumed only 815 grains, or 0 1164 of a lb. per hour. If we multiply this number into the price of the oil (8*s.* per gallon) per lb. 11*d.*, the product 1·2804*d.* will represent the relative cost of this illumination, estimated at 100.

2. The hot-oil lamp burns with a much steadier flame than the mechanical, which must be ascribed in no small degree to the rounded slope of the bell-mouthed glass chimney, whereby the air is brought progressively closer and closer into contact with the outer surface of the flame, without being furiously dashed against it, as it is by the rectangular shoulder of the common contracted chimney. When charged with sperm oil, and made to burn with its maximum flame, this lamp required to be placed one foot further from the screen than the mechanical lamp, in order that its shadow should have the same depth of tint. Hence, its relative illumination was, in that case, as the square of 11 to the square of 10; or as 121 to 100. Yet its consumption of oil was only 696 grains, or somewhat less than 0·1 of a lb. per hour. Had its light been reduced to 100, it would have consumed only 576 grains per hour, or ·082 of a lb. If we multiply this number by 11*d.*, the product 0·902*d.* will represent the relative cost of 100 of this illumination.

3. The hot-oil lamp being charged with the southern whale oil, of specific gravity 0·926, at 2*s.* 6*d.* per gallon, or 3¾*d.* per lb., when burning with its maximum flame, required to be placed 9 feet and 1 inch from the screen to drop the same tint of shadow upon it as the flames of the other two lamps did at 10 and 11 feet with the sperm oil. The square of 9 feet and 1 inch = 82 is the relative illumination of the hot-oil lamp

with the southern whale oil. It consumed 780 grains, or 0·111 of a pound per hour; but had it given 100 of light it would have consumed 911 grains, or 0·130 of a pound, which number being multiplied by its price 3¾*d.*, the product 0·4875*d.* will represent the relative cost of 100 of this light.

4. A hot-oil lamp charged with olive oil of specific gravity 0·914, at 5*s.* 6*d.* per gallon, or 7½*d.* per lb. when burning with its maximum flame, required to be placed at 9 feet 6 inches, to obtain the standard tint of shadow upon the screen. It consumed 760 grains per hour. The square of 9½ feet is 90¼, which is the relative intensity of the light of this lamp. Had it emitted a light = 100, it would have consumed 840 grains, or 0·12 of a pound per hour—which number multiplied by the price per pound, gives the product 0·9*d.* as the relative cost of 100 of this light.

5. A hot-oil lamp charged with Price and Co.'s cocoa-nut oil (oleine), of specific gravity 0·925, at 4*s.* 6*d.* per gallon, or 5¾*d.* per lb., had to be placed 9 feet from the screen, and consumed 1035 grains per hour. Had its light been 100 instead of 81 (9²), the consumption would have been 1277 grains, or 0·182 of a pound per hour! which number multiplied by its price per pound, the product 1·031*d.* will represent the cost of 100 of this illumination.

6. In comparing the common French annular lamp in general use with the mechanical lamp, it was found to give about one-half the light, and to consume two-thirds of the oil of the mechanical lamp.

7. Wax candles from some of the most eminent wax-chandlers of the metropolis were next subjected to experiment; and it is very remarkable that, whether they were threes, fours, or sixes in the pound, each afforded very nearly the same quantity of light, for each required to be placed at a distance of 3 feet from the screen to afford a shadow of the same tint as that dropped from the mechanical lamp, estimated at 100. The consumption of a genuine wax candle, in still air, is, upon an average of many experiments, 125 grains per hour, but as it affords only $\frac{1}{11}$ of the light of the mechanical lamp, 11 times 125 = 1375 grains, or 0·1064 of a pound is the quantity that would need to be consumed to produce a light equal to that of the said lamp. If we multiply that number by the price of the candles per lb. = 30*d.* the product = 5·892*d.* is the cost of 100 of illumination by wax. A wax candle, three in the pound (short), is one inch in diameter, 12 inches in length, and contains 27 or 28 threads, each about $\frac{1}{50}$ of an inch in diameter. But the quality of the wick depends upon the capillarity of the cotton fibrils, which is said to be greatest in the Turkey cotton, and hence the wicks for the best wax candles are always made with cotton yarn imported from the Levant. A wax candle, three in the pound (long), is ⅞ of an inch in diameter, 15 inches long, and has 26 threads in its wick. A wax candle, six to the pound, is 9 inches long, ¾ of an inch in diameter, and has 22 threads in its wick. The light of this candle may be reckoned to be, at most, about $\frac{1}{11}$ less than that of the threes in the pound. A well-made short three burns with surprising regularity in still air, being at the rate of an inch in an hour and a half, so that the whole candle will last 18 hours. A long three will last as long, and a six about 9½ hours. Sp. gr. of wax = 0·960.

8. A spermaceti candle, three in the pound, is $\frac{8}{10}$ of an inch in diameter, 15 inches long, and has a plaited wick, instead of the parallel threads of a wax candle. The same candles four in the pound, are $\frac{6}{10}$ of an inch in diameter, and 13½ inches long. Each gives very nearly the same quantity of light as the corresponding wax candles: viz. $\frac{1}{11}$ of the light of the above mechanical lamp, and consumes 142 grains per hour. Multiplying the last number by 11, the product, 1562 grains = 0·223 of a pound, would be the consumption of spermaceti requisite to give 100 of illumination. Multiplying the last number by 24*d.*, the price of the candles per pound, the product, 5·352*d.* is the relative cost of 100 of this illumination.

9. *Stearic acid* candles, commonly called German wax, consume 168·5 grains, or 0·024 of a pound per hour, when emitting the same light as the standard wax candle. Multiplying the latter number by 11, and by 16*d.* (the price of the candles per lb.), the product 4·224*d.* will represent the relative cost of 100 of this illumination.

10. Tallow candles: moulds, short threes, 1 inch in diameter, and 12½ in length; ditto long threes, $\frac{8}{10}$ of an inch in diameter, and 15 in length; ditto, long fours, $\frac{7}{10}$ of an inch in diameter, and 13¾ in length. Each of these candles burns with a most uncertain light, which varies from $\frac{1}{13}$ to $\frac{1}{16}$ of the light of the mechanical lamp—the average may be taken at $\frac{1}{14}$. The threes consumes each 144 grains, or 0·2 of a pound, per hour; which number, multiplied by 14, and by 9*d.* (the price per pound), gives the product 2·52*d.* for the relative cost of 100 of this illumination.

11. *Palmer's* spreading wick candles. Distance from the screen 3 feet 4 inches, with a shadow equal to the standard. Consumption of tallow per hour 232·5 grains, or 0·0332 of a pound. The square of 3 feet 4 inches = 11·9 is the relative illumination of this candle = 11·9 : 0·3332 :: 100 : 0·28 × 10*d.* = 11·9 is the relative cost of this illumination.

12. Cocoa-nut stearine candles consumed each 168 grains per hour, and emitted a light equal to $\frac{1}{16}$ of the standard flame. Multiplying 168 by 16, the product 30·88 grains, or 0·441 of a lb., is the quantity which would be consumed per hour to afford a light equal to 100. And 0·441 multiplied by 10*d.*, the price per lb., gives the product 4·441*d.* as the cost of 100 of this illumination per hour.

13. A gas Argand London lamp, of 12 holes in a circle of $\frac{3}{4}$ of an inch in diameter, with a flame 3 inches long, afforded a light = 78½ compared to the mechanical lamp: and estimating the light of the said mechanical lamp as before at 100, that of the hot-oil lamp is 121, and that of the above gas flame 78·57, or in round numbers 80, *and the common French lamp in general use* 50.

Collecting the preceding results, we shall have the following tabular view of the cost per hour of an illumination equal to that of the mechanical lamp, reckoned 100, or that of eleven wax candles, three to the pound.

TABLE of COST per HOUR of ONE HUNDRED of ILLUMINATION.

	Pence.	Pence.
1. Parker's hot-oil lamp, with southern whale oil -	0·4875 or about	½*d.*
2. Mechanical or Carcel lamp, with sperm oil - -	1·2804 - -	1¼
3. Parker's hot-oil lamp, with sperm oil - - -	0·902 - -	1
4. Ditto ditto common olive oil - -	0·900 - -	1
5. Ditto ditto cocoa-nut oleine or oil -	1·031 - -	1
6. French lamp in general use, with sperm oil - -	1·7072 - -	1¾
7. Wax candles - - - - - - -	5·892 - -	6
8. Spermaceti candles - - - - - -	5·352 - -	5½
9. German wax (Stearic acid) ditto - - - -	4·224 - -	4¼
10. Palmer's spreading wick candles - - - -	2·800 - -	2⅞
11. Tallow (mould) candles - - - - -	2·520 - -	2½
12. Cocoa-nut stearine of Price and Co. - - -	4·41 - -	4½

The following table contains, according to Péclet, the illuminating powers of different candles, and their consumption of material in an hour; the light emitted by a *Carcel* Argand lamp, consuming 42 grammes (= 42 × 15½ grains) in an hour, being called 100:—

	Intensity of Light.	Consumption per Hour.
Tallow candles 6 in lb. - - -	10·66	8·51
Stearine, or pressed tallow, 8 in lb. -	8·74	7·51
——————, 5 in lb. -	7·50	7·42
Wax candles, 5 in lb. - - -	13·61	8·71
Spermaceti, 5 in lb. - - - -	14·40	8 92
Stearic acid, commonly called stearine, 5 in lb. - - - - - -	14·40	9·33

The subjoined table shows the economical ratios of the candles, where the second column gives the quantity of material in grammes which is requisite to produce as much light as the Carcel lamp:—

	Quality of Material.	Price per Kilogramme.	Cost of Light per Hour.
Tallow candle, 6 per lb. - -	70·35	1 f. 40 c.	9·8 c.
——————, 8 per lb. - -	85·92	1 f. 40 c.	12·0 c.
Pressed tallow, 5 per lb. - -	98·93	2 f. 40 c.	23·7 c.
Wax candle, 5 per lb. - -	64·04	7 f. 60 c.	48·6 c.
Spermaceti ditto, 5 per lb. -	61·94	7 f. 60 c.	47·8 c.
Stearine, 5 per lb. - - -	65·24	6 f.	37·1 c.

These results may be compared with mine given above. A kilogramme, or 1000 grammes = 15,440 grains = 2¼ lbs. avoirdupois."—*Ure.*

The rule observed in the determination of these questions of illuminating power, is, according to the laws of optics, that the sum of the impinging rays from any source, is inversely as the square of the distance from their source.

"The numerical estimation of the degrees of intensity of light constitutes that branch of optics which is termed PHOTOMETRY.

"If light be a material emanation, a something scattered in minute particles in all directions, it is obvious that the same quantity which is diffused over the surface of a sphere concentric with the luminous points, if it continue its course, will successively be diffused over larger and larger concentric spherical surfaces; and then its intensity, or the number of rays which fall on a given space, in each will be inversely as the whole surfaces over which it is diffused; that is, inversely as the square of their radii, or of their distances from the source of light. . . . . Let a candle be placed behind an opaque screen, full of small equal and similar hŏles: the light will shine through these, and be intercepted in all other parts, forming a pyramidical bundle of rays, having the candle in the common vertex. If a sheet of white paper be placed behind this, it will be seen dotted over with small luminous specks, disposed exactly as the holes in the screen. Suppose the holes so small, their number so great, and the eye so distant from the paper, that it cannot distinguish the individual specks, it will still receive a general impression of brightness; the paper will appear illuminated, and present a mottled appearance, which, however, will grow more uniform as the holes are smaller and closer, and the eye more distant, and if extremely so, the paper will appear uniformly bright. Now if every alternate hole be stopped, the paper will manifestly receive only half the light, and will therefore be only half as much illuminated; and *cæteris paribus* the degree of illumination is proportional to the number of holes in the screen, or to the number of equally illuminated specks on the surface; *i. e.* if the speck be infinitely diminished in size, and infinitely increased in number to the number of rays which fall on it from the original source of light." (*Herschel.*) Reasoning thus, Sir John Herschel proceeds and establishes the following definitions:—

The real intrinsic brightness of a luminous object is the intensity of the light of each physical point in its surface.

The apparent intrinsic brightness of any object or luminary is the degree of illumination of its image or picture at the bottom of the eye.

The absolute light of a luminary is the sum of the areas of its elementary portions, each multiplied by its own intrinsic brightness.

The apparent light of an object is the total quantity of light which enters our eyes from it, however distributed on the retina.

Various instruments, called *photometers*, have been devised to measure the illuminating power of any body; these are, all of them, more or less defective, and the results which we obtain with the best of them are merely comparative with each other.

Bouguer's photometer consisted of two surfaces of white paper, of exactly equal size and reflective power, cut from the same piece in contact; these are illuminated, the one by the light whose illuminating power is to be measured; and the other by a light whose intensity can be varied at pleasure by an increase of distance, and can therefore be exactly estimated. The variable light is to be removed or approached, till the two surfaces are judged to be equally bright, when the distances of the luminaries being measured, or otherwise allowed for, the measure required is ascertained.

Rumford's photometer. Before a screen of white paper, in a darkened room, is placed a blackened cylindrical stick, and the two lights to be compared are so placed that two shadows are thrown upon the screen side by side, with an interval between them about equal in breadth to either shadow. The brighter flame must then be removed, or the feebler brought nearer to the screen, till the two shadows appear of equal intensity, when their distances from the lights must be measured, and their total illuminating powers will be in the direct ratio of the squares of the distances.

Ritchie's photometer consists of a rectangular box, about an inch and a half or two inches square, open at two ends. It is blackened within to absorb the extraneous light. Within, inclined at angles of 45° to its axis, are placed two rectangular pieces of plain looking-glass, cut from one and the same rectangular strip; these are fastened so as to meet in the middle of a narrow slit, about an inch long, and an eighth of an inch broad, which is covered with a slip of fine tissue or oiled paper, and a blackened card prevents the reflected images from mingling. If we would compare two lights, they must be placed at such a distance from each other, and from the instrument between them, that the light from every part of each shall fall on the reflector next it, and be reflected to the corresponding portion of the paper. The instrument is then to be moved nearer to the one or the other, till the paper on either side of the division appears equally illuminated. When the lights are thus exactly equalised, it is clear that the total illuminating powers of the luminaries are directly as the squares of their distances from the middle of the instrument.

Wheatstone's photometer is a small sphere with a reflecting surface, which being placed between the two lights, each light is seen on it by the spectator, the two being reflected from different points of the sphere's surface. By an ingenious but simple

mechanical contrivance, a rapid looped motion is communicated to the ball, and by the principle of the *persistence of impressions*, the spectator immediately sees two looped curves of different brightnesses. The brighter light is removed until these curves seem of the same brightness, and the intensities of the luminous points are then as the squares of the distances.

Bunsen's photometer consists of a sheet of cream coloured letter paper, rendered transparent over a portion of the surface by a mixture of spermaceti and rectified naphtha, which is solid at common temperatures, but becomes liquid on the application of a very gentle heat. The mixture is liquefied and painted over the paper with a brush, leaving a round disc of the size of half a crown in the centre uncovered. When a light is placed on one side of the paper a dark spot is observed on the uncovered portion. When another light is placed on the other side of the paper, the spot is still distinctly visible, if the distance of the light is such that the reflected portion from the paper be either of greater or of less intensity than that transmitted. When the paper is so situated between the two flames that the transmitted and reflected light are of the same intensity, the uncovered spot is no longer visible.

It will be evident from these descriptions that it is possible only, by any of these contrivances, to compare one light with another; there is not any arrangement by which we are enabled to express absolutely the illuminating power. Upon the principle of comparison, and comparison only, the following tables have been constructed by the relative experimentalists. The observations of Péclet have been already given. The following comparative view of wax and stearine candles manufactured in Berlin, which have been deduced from the observations of Schubarth, is of much value.

Kind of candles, and whence obtained.		Relative intensity of light.	Consumption in one hour, in grammes.	Relative illuminating power.
Common wax candles, of Tannhänser	4's	103·5	7·877	85·20
	6's	91·0	7·176	83·20
	8's	100·0	6·562	100·0
Wax candles, of Walker	4's	132·7	9·398	92·66
	6's	120·3	8·082	97·69
	8's	113·1	7·132	104·1
Stearine candles, of Motard	4's	117·4	9·427	81·74
	6's	111·8	9·383	78·23
	8's	121·0	7·877	100·7
Stearine candles, of Magnet and Oehmichen	4's	139·5	10·63	86·11
	6's	132·7	9·398	92·66
	8's	125·0	8·506	96·54
Stearine candles, from the same makers	6's	116·1	8·871	85·86
	8's	146·0	8·886	108·0
Candles made from palm oil	4's	124·5	9·880	82·67
	6's	115·3	9·178	82·56
	8's	167·5	8·813	113·70

These results show us that the mean illuminating power of wax and stearine candles is nearly the same.

The illuminating power of gases and of gas burners will be found in the article COAL GAS.

IMPERMEABLE, is the epithet given to any kind of textile fabric, rendered water-proof by one or other of the following substances; —

1. Linseed oil to which a drying quality has been communicated by boiling with litharge or sugar of lead, &c.

2. The same oil holding in solution a little caoutchouc.

3. A varnish made by dissolving caoutchouc in rectified petroleum or naphtha, applied between two surfaces of cloth, as described under Macintosh's patent. See CAOUTCHOUC.

4. Vegetable or mineral pitch, applied hot with a brush, as in making tarpauling for covering goods in ships.

5. A solution of soap worked into cloth, and decomposed in it by the action of a solution of alum; whence results a mixture of acid, fats, and alumina, which insinuates itself among all the woolly filaments, fills their interstices, and prevents the passage of water.

6. A solution of glue or isinglass, introduced into a stuff, and then acted upon by a clear infusion of galls, whereby the fibres get impregnated with an insoluble, impermeable, pulverulent leather.

7. Plaster work is rendered impermeable by mixing artificial or natural asphaltum with it.

INCUBATION, ARTIFICIAL. The Egyptians have from time immemorial been accustomed to hatch eggs by artificial warmth, without the aid of hens, in peculiar stoves, called *Mammals*. M. de Reaumur published in France, about a century ago, some ingenious observations upon this subject; but M. Bonnemain was the first person who studied with due attention all the circumstances of artificial incubation, and mounted the process successfully upon the commercial scale. So far back as 1777 he communicated to the Academy of Sciences an interesting fact, which he had noticed, upon the mechanism employed by chicks to break their shells; and for some time prior to the French revolution he furnished the Parisian market with excellent poultry at a period of the year when the farmers had ceased to supply it. His establishment was ruined at that disastrous era, and no other has ever since been constructed or conducted with similar care. His apparatus derives peculiar interest from the fact that it was founded upon the principle of the circulation of hot water, by the intestine motions of its particles, in a returning series of connected pipes; a subject afterwards illustrated in the experimental researches of Count Rumford. It has of late years been introduced as a *novelty* into this country, and applied to warm the apartments of many public and private buildings. The following details will prove that the theory and practice of hot water circulation were as perfectly understood by M. Bonnemain fifty years ago, as they are at the present day. They were then publicly exhibited at his residence in Paris, and were afterwards communicated to the world at large in the interesting article of the *Encyclopédie Technologique*, intitled *Incubation Artificielle*, under the head of *Régulateur de Température*.

The apparatus of M. Bonnemain consisted: 1, of a boiler and pipes for the circulation of water; 2, of a regulator calculated to maintain an equable temperature; 3, of a stove-apartment, heated constantly to the degree best fitted for incubation, which he called the *hatching* pitch. He attached to one side a *poussinière* or chick-room, for cherishing the chickens during a few days after incubation.

The boiler is represented in vertical section and ground plan, in *figs.* 987 and 988. It is composed of a double cylinder of copper or cast iron *l*, *l*, having a grate *b* (see plan), an ashpit at *d* (section). The water occupies the shaded space c, c. *h*, *g*, *g*, *e*, *e*, are five vertical flues for conducting the burnt air and smoke, which first rise in the two exterior flues *e*, *e*, then descend in the two adjoining flues *g*, *g*, and finally remount through the passages *i*, *i*, in the central flue *h*. During this upwards and downwards circulation, as shown by the arrows in the section, the products of combustion are made to impart nearly the whole of their heat to the water by which they are surrounded. At the commencement, some burning paper or wood shavings are inserted at the orifice *m*, to establish a draught in this circuitous chimney. The air is admitted into the ashpit at the side, in regulated quantities, through a small square door, movable round a rod which runs horizontally along its middle line. This swing valve is acted upon by an expanding bar (see HEAT-REGULATOR), which opens it more or less, according to the temperature of the stove apartment in which the eggs are placed.

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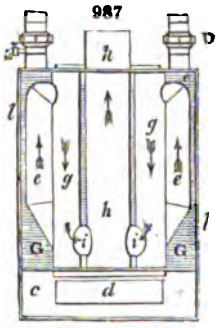

D is the upper orifice of the boiler, by which the hotter and consequently lighter particles of the water continually ascend, and are replaced by the cooled particles, which enter the boiler near its bottom, as shown in *fig.* 989 at R. Into further details relative to the boiler it is needless to enter; for though its form, as designed by M. Bonnemain, is excellent and most economical of heat for a charcoal fire, it would not suit one of pit-coal, on account of the obstruction to the pipes which would soon be caused by its soot.

In *fig.* 989 the boiler is shown at R, with the rod which regulates the air door of the ashpit. D is a stopcock for modifying the opening by which the hotter particles of water ascend; G is the water pipe of communication, having the heating pipe of distribution attached between E F, which thence passes backwards and forwards with a very slight slope from the horizontal direction, till it reaches the *poussinière* O P Q. It traverses this apartment, and returns by N N to the orifice of the boiler H, where it turns vertically downwards, and descends to nearly the bottom of the boiler, discharging at that point the cooled and therefore denser particles of water to replace those which continually issue upwards at D. L R is a tube surmounted with a funnel for keeping the range of pipes always full of water; and K is a siphon orifice for permitting the escape of the disengaged air, which would otherwise be apt to occupy partially the pipes and obstruct the aqueous circulation.

The faster the water gets cooled in the serpentine tubes, the quicker its circulation will be, because the difference of density between the water at the top and bottom of

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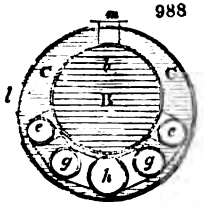

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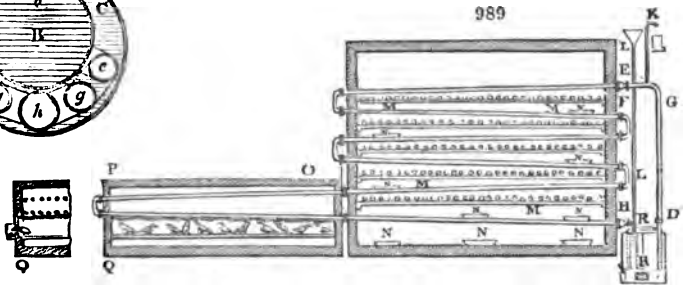


the boiler, which is the sole cause of its movement, will be greater. N represents small saucers filled with water, to supply the requisite moisture to the heated air, and to place the eggs, arranged along the trays M M, in an atmosphere analogous to that under the body of the hen.

When we wish to hatch eggs with this apparatus, the fire is to be kindled in the boiler, and as soon as the temperature has risen to about 100° F., the eggs are introduced; but only one-twentieth of the whole number intended, upon the first day: next day a like number is laid upon the trays, and thus in succession for twenty days, so that upon the twenty-first day the eggs first placed may be hatched for the most part, and we may obtain daily afterwards an equal number of chicks. In this way regularity of care is established in the rearing of them.

During the first days of incubation, natural as well as artificial, a small portion of the water contained in the egg evaporates by the heat, through the shell, and is replaced by a like quantity of air, which is afterwards useful for the respiration of the animal. If the warm atmosphere surrounding the eggs were very dry, such a portion of the aqueous part of the eggs would evaporate through the pores of the shells as would endanger the future life of the chick *in ovo*. The transpiration from the body of the hen, as she sits upon her eggs, counteracts this desiccation in general; yet in very dry weather many hatching eggs fail from that cause, unless they be placed in moist decomposing straw. The water saucers N N are therefore essential to success in artificial incubation.

After the chickens are hatched they are transferred into the nursery, O Q, on the front side of which there is a small grated trough filled with millet seed. Small divisions are made between the broods of successive days, to enable the superintendent to vary their feeding to their age.

In order to supply an establishment of the common kind, where 100 eggs are to be hatched daily, a dozen of hens would be needed, and 150 eggs must be placed under them, as only two-thirds in general succeed. At this rate, 4300 mothers would be required to sit. Now supposing we should collect ten times as many hens, or 43,000, we should not be able to command the above number of chickens, as there is seldom a tenth part of hens in a brooding state. Besides, there would be in this case no fewer than 720 hens every day coming out with a fresh brood of chickens, which would require a regiment of superintendents.

Artificial Incubation by means of Hot Mineral Waters. — This curious process is described very briefly in a letter by M. D'Arcet. The following are extracts from his letter: —

"In June, 1825, I obtained chickens and pigeons at Vichy, by artificial incubation, effected through the means of the thermal waters of that place. In 1827 I went to the baths of Chaudes-Aigues, principally for the purpose of doing the same thing there. Finding the proprietor a zealous man, I succeeded in making a useful application of this source of heat to the production of poultry.

"The advantage of this process may be comprehended, when it is known that the invalids who arrive at Vichy, for instance in the month of May, find chickens only the size of quails; whereas, by this means, they may be readily supplied six months old.

"The good which may be done by establishing artificial incubation in places where hot springs exist, is *incalculable*; it may be introduced into these establishments without at all interfering with the medical treatment of patients, since the hatching would go on in winter, at a time when the baths for other purposes are out of use.

"There is no other trouble required in breeding chickens, by means of hot baths, than to break the eggs at the proper time; for, when the apartments are closed, the whole of the interior will readily acquire a sufficiently elevated and very constant temperature."

INCOMBUSTIBLE CLOTH is a tissue of the fibrous mineral called amianthus or asbestos. This is too rare to form the object of any considerable manufacture. Cotton and linen cloth may be best rendered incapable of burning with flame by being imbued with a solution of sal ammoniac or of alum.

INDIAN INK, or CHINA INK. A very beautiful black pigment, the best varieties of which are obtained from China. Many absurd stories have been told about Indian ink. It is composed of a very fine black, cemented together with some kind of animal gelatine. It has been thought by Prechol to be a black obtained from camphor, which is not improbable. See INK.

INDIAN MATTING. Mats made in India from the long grass or reed *Papyrus corymbosus*.

INDIAN RUBBER. See CAOUTCHOUC.

INDIAN YELLOW. This is a peculiar precipitate obtained from the urine of the cow, and, according to some authorities, of the camel, after the animal has been eating decayed and yellow mango leaves — the *Mangistana mangifer*. It appears to be composed of magnesia with a yellow body which may be prepared pure by boiling the mass with water, to which small quantities of muriatic acid are added, until the whole dissolves, and then filtering. On cooling, the liquor deposits the colouring matter in brilliant yellow scales, which are termed *purreic acid* (*Kane*). See *Ure's Chemical Dictionary* for this acid and its derivatives.

INDIGO. This invaluable dye-stuff consists essentially of a blue colouring matter, to which the name of *Indigo-blue* has been applied. This colouring matter occurs in the leaves of several species of plants, which, though few in number, belong to very different genera and orders. The only native European plant which is known with certainty to yield it is the *Isatis tinctoria*, or common woad. It has also been supposed to occur in the following plants, all of which are natives of Europe, viz.: — *Astragalus glycyphyllus, Centaurea Cyanus, Chelidonium majus, Cicer arietinum, Colutea arborescens, Coronilla Emerus, Galega officinalis, Hedysarum Onobrychis, Inula Helenium, Iris Germanica, Lotus corniculatus, Medicago sativa, Mercurialis perennis, Polygonum aviculare, Polygonum Fagopyrum, Rhinanthus Crista-galli, Sambucus nigra, Sambucus Ebulus, Scabiosa succisa* and *Vaccinium Myrtillus*. According to the investigations of Giobert and others, however, none of these plants afford any indigo-blue, though several of them, such as the *Mercurialis perennis*, contain a blue colouring matter of a peculiar nature. The indigo-bearing plants growing in tropical countries furnish far more indigo-blue than the *Isatis tinctoria*. Such are the various species of *Indigofera*, natives of the East and West Indies, the *Nerium tinctorium* and *Calanthe veratrifolia* of Hindostan, the *Asclepias tinctoria* and *Marsdenia tinctoria* of Sumatra, the *Polygonum tinctorium*, the *Isatis indigotica*, the *Justicia tinctoria*, and the *Bletia Tankervillæ*, of China, and the *Amorpha fruticosa* of Carolina. Most of these plants belong to the natural order Leguminosæ. The others belong respectively to the orders Cruciferæ, Apocyneæ, Asclepiadeæ, Polygoneæ, Acanthaceæ, and Orchideæ. Indigo-blue has sometimes been observed to form in the milk of cows, especially such as have been fed exclusively on saint-foin. It has also been found by Prout, Hassall, and others in the urine of individuals suffering from various diseases, and Schunck has lately shown that the urine of men and animals, even when in a perfectly healthy state, may be made to yield indigo-blue in small quantities by treatment with strong acids. Hence it appears that this colouring matter may be obtained from a variety of sources, though it is nowhere found in great abundance.

The use of woad for the purpose of dyeing blue seems to have been known in Europe from the earliest times. We are told by Cæsar that the Britons stained their bodies blue with woad, in order to give themselves a more formidable appearance in battle; and Pliny informs us that their women, before entering on certain sacred rites, which were performed in a state of nudity, employed the same means of colouring their bodies, whereby they acquired the appearance of negroes. During the middle ages the cultivation of woad was carried on very extensively in several countries of Europe, especially in Thuringia in Germany, in the province of Languedoc in France, and in the neighbourhood of Rieti in Italy. The leaves of the plant were ground into a pulp, and then submitted to a long process of fermentation, by which means they were converted into a mass of a dark colour which was moulded into balls for the use of the dyer. (See WOAD.) No attempt to extract the blue colouring matter from the plant seems, however, to have been made before the commencement of the present century.

Whether indigo in its present form was known to the ancients has been doubted.

Pliny and Dioscorides refer to a pigment called *Indicum*, which seems to have been of a blue colour, though there is little doubt that the article to which the name *Indicum nigrum* was applied was identical with our Indian ink. Of indicum Pliny says that it comes from India and is obtained from the slime adhering to reeds; that it is black when rubbed, but of a fine mixture of purple and blue when dissolved; and that there is another kind which is found swimming on the dye-vessels where purple is dyed, this being the scum of the purple-fish. He adds that those who adulterate indicum dye pigeon's dung or chalk with woad, but that the genuine substance may be known by heating it, when it gives a beautiful purple vapour and emits a smell like that of the sea, and for this reason it has been supposed to be obtained from the rocks. It can hardly be doubted that in this passage indigo is referred to, and that the second kind of indicum mentioned by Pliny consisted probably of the scum of indigo-blue found floating on the surface of the liquor in which the dyeing was performed. It seems, however, that at that time the colouring matter was not so completely separated from the other vegetable matters of the plant as at the present day, since pigeon's dung coloured with woad would bear very little resemblance to our present indigo, but would be a fair imitation of the preparation usually made from woad. It is probable, therefore, that at that period the process of manufacturing indigo was a very rude one, and consisted merely in the separation of a portion of the vegetable from the remainder. Even at the present day the natives of some countries, where the arts have not attained any high degree of development, produce an article from indigo-bearing plants which serves the purpose of dyeing blue, though not much resembling indigo in appearance. In Sumatra, for instance, as Marsden informs us, the natives do not manufacture indigo into a solid substance, but leave the stalks and branches for some days in water to soak and macerate, then boil it, and work with their hands some *chunam* (quicklime) among it, with leaves of the *pacoo saba* (a species of fern) for fixing the colour, after which they drain it off and use it in the liquid state. On the west coast of Africa the leaves of the indigo plant are moulded into balls, which are then dried in the sun and stored up until they are wanted. These balls, which have a slight blue tint, may be preserved a long time and be transported to great distances. When they are to be used for dyeing they are broken and reduced to a fine powder. This powder is then mixed with water to which the ashes of a certain plant are added, and the liquid is boiled in large earthenware vessels of a conical form, when it assumes a deep blue colour and is then ready for dyeing the fabrics which are plunged into it.

The article known as indigo in the middle ages must have been very similar to the indigo of the present day; for though Marco Polo had described the manner in which the substance was produced from the plant, it was for a long time considered as a mineral; and even in the letters patent obtained in 1705 by the proprietors of mines in the principality of Halberstadt, it was classed among minerals on account of which works were suffered to be erected.

Indigo seems to have been first extensively used in Europe by the Jewish dyers, who introduced it into the dye-houses of Italy. It was not, however, imported in any large quantities until the discovery of the passage round the Cape of Good Hope. At the beginning of the 17th century, the Dutch commenced carrying on an extensive trade with the East, and indigo was one of the articles which they imported in large quantities into European countries. Its use was found to be attended with so many advantages, that the employment of woad for the same purpose was gradually abandoned. The colour produced by it was more brilliant and far cheaper than the blue from woad. On the other hand it was asserted that the goods dyed with indigo faded rapidly, and that the vitriol and other corrosive substances used along with it caused them, after some time, to rot. At the same time the exportation of large sums of money in payment for indigo, and the rapid decline in the cultivation of woad, which had previously furnished occupation to great numbers of people in various countries of Europe, and had been the source of great wealth to individuals, caused so much alarm, that the most stringent measures were adopted in order to prevent the use of indigo in dyeing. A decree of the Germanic diet held at Frankfort, in 1577, prohibited, under the severest penalties, the newly invented, pernicious, deceitful, eating and corrosive dye, called the *devil's dye*, for which vitriol and other cheaper materials were used instead of woad. This prohibition was renewed in 1594 and 1603. In the year 1650, the Elector of Saxony prohibited the sale and importation into his dominions of all fabrics dyed with other materials in the place of woad. This was followed by an imperial mandate issued from Ratisbon, in the year 1654, forbidding the importation and the use by dyers of indigo and other injurious substances, and threatening with punishment and the confiscation of their goods all persons who should offer for sale any cloth dyed with forbidden and deceitful dyes instead of with the permanent colour of woad. The people of Nuremberg even went so far as to compel their dyers by law

annually to take oath, not to employ indigo, and this was continued down to a very recent period, though it was well known that its use was indispensable to them. In France, the use of indigo was forbidden in 1598, in consequence of an urgent representation by the states of the province of Languedoc, and this prohibition was afterwards repeated several times. But in the well-known edict of 1669, in which Colbert separated the fine from the common dyers, it was stated that indigo should be used without woad; and in 1737, dyers were left at liberty to use indigo alone, or to employ a mixture of indigo and woad. In England the use of indigo was also forbidden, and by an act passed in the reign of Elizabeth, searchers were authorised to burn both it and logwood in every dye-house where they could be found. This act remained in force for nearly a century.

It has been doubted whether the plant which is employed in America for the manufacture of indigo is a native of that continent, or whether it was introduced by the Spaniards. It was remarked by the first voyagers on the new continent that the natives coloured their bodies and dyed their stuffs by means of indigenous plants which resembled the indigo plant of Asia. Fernando Columbus, in the life of his father, says, that this plant grew in a wild state in the West India Islands, and that it was cultivated for the purpose of obtaining from it a blue pigment. Hernandes mentions it among the native plants of Mexico, and says, that the Americans used it for dyeing their hair black. He adds, that they made from it a pigment, which they named *mohuitli* and *tleuohuilli*, the same as the *cæruleum* of the Latins, and he describes also the method of preparing it. Nevertheless it appears that the *Indigofera tinctoria* and *Anil* were really introduced into America by the Spaniards, and were the plants employed by them for the manufacture of indigo in Mexico, Guatemala, and St. Domingo, though some of the varieties produced by the influence of the climate and soil differ very widely in appearance from the parent stock. The manufacture of indigo was at one time carried on extensively in Central America and the West India Islands, and these countries formerly supplied the chief portion of the article consumed in Europe. The indigo of Guatemala at the same time surpassed all others in quality. In consequence however, of the political disturbances in America, and the great improvements which have been effected in the manufacture of indigo by the zeal and perseverance of our countrymen in the East, its production in America has diminished very much, and at the present day, the indigo consumed in Europe is derived chiefly from India, and more especially from Bengal, Oude, and Madras. The remainder is imported from Java, Manilla, the Mauritius, and Senegal in the eastern hemisphere, and from Caraccas, Brazil, and Gautemala in the western. The East Indian and Brazilian indigo comes packed in chests, the Guatemala in ox-hides, called *serons*. Its quality depends upon the species of the plant, its ripeness, the soil and climate of its growth, and the mode of manufacture.

The plants which are cultivated in the East Indies, are the *Indigofera tinctoria*, *Anil*, *disperma and pseudo-tinctoria*. The districts of Kishenagar, Jessore, and Moorshedabad, in Bengal, ranging from 88° to 90° east lat. and 22¾° to 24° north long., produce the finest indigo. That from the districts about Burdwan and Benares is of a coarser or harsher grain. Tyroot, in lat. 26°, yields a tolerably good article. The portion of Bengal most propitious to the cultivation of indigo, lies between the river Hoogly and the main stream of the Ganges. The ground having been ploughed in October, November, or beginning of December, the seed of the indigo plant is sown in the last half of March or beginning of April, while the soil being neither too hot nor too dry, is most propitious to its germination. A light mould answers best; and sunshine, with occasional light showers, are most favourable to its growth. From twenty-four to thirty pounds of seeds are required for sowing an acre of land. The plants grow rapidly, and will bear to be cut for the first time at the beginning of July, nay, in some districts, so early as the middle of June. The indications of maturity are the bursting forth of the flower buds, and the expansion of the blossoms; at which period the plant contains most colouring matter. Another indication is taken from the leaves; which, if they break across, when doubled flat, denote a state of maturity. But this character is somewhat fallacious, and depends upon the poverty or richness of the soil. When much rain falls, the plants grow too rapidly, and do not sufficiently elaborate the blue pigment. Bright sunshine is most advantageous to its production. The first cropping of the plants is best; after two months a second is made; but at the present day, planters never undertake a third or fourth.

Two methods are pursued to extract the indigo from the plant; the first effects it by fermentation of the fresh leaves and stems; the second, by maceration of the dried leaves.

1. *From the recent leaves.* — In the indigo factories of Bengal, there are two large stone-built cisterns, the bottom of the first being nearly upon a level with the top of the second, in order to allow the liquid contents to be run out of the one into the other.

The uppermost is called the fermenting vat, or the steeper; its area is 20 feet square, and its depth 3 feet; the lowermost, called the beater or beating vat, is as broad as the other, but one third longer. The cuttings of the plant, as they come from the field, are stratified in the steeper, until this is filled to within 5 or 6 inches from its brim. In order that the plant, during its fermentation, may not swell and rise out of the vat, beams of wood and twigs of bamboo are braced tightly over the surface of the plants, after which water is pumped upon them until it stands about 3 or 4 inches from the edge of the vessel. An active fermentation speedily commences, which is completed within 14 or 15 hours, a little longer or shorter, according to the temperature of the air, the prevailing winds, the quality of the water, and the ripeness of the plants. Nine or ten hours after the immersion of the plant, the condition of the vat must be examined; frothy bubbles are then seen rising like little pyramids, at first of a white colour, but soon becoming greyish-blue, and then deep purplish-red. The fermentation is at this time violent, the fluid being in constant commotion, and apparently boiling, innumerable bubbles mount to the surface, and a dense copper-coloured scum covers the whole. As long as the liquor is agitated, the fermentation must not be disturbed; but when it becomes more tranquil, the liquor is to be drawn off into the lower cistern. It it of the utmost consequence not to push the fermentation too far, because the quality of the whole indigo is thereby deteriorated; but rather to cut it short, in which case there is, indeed, a loss of weight, but the article is better. The liquor possesses now a glistening yellow colour, which, when the indigo precipitates changes to green. The average temperature of the liquor is commonly 85° Fahr.; its specific gravity at the surface is 1·0015; and at the bottom 1·003.

As soon as the liquor has been run into the lower cistern, ten men are set to work to beat it with oars or shovels 4 feet long, called *busquets*. Paddle wheels have also been employed for the same purpose. Meanwhile two other labourers clear away the compressing beams and bamboos from the surface of the upper vat, remove the exhausted plant, set it to dry for fuel, clean out the vessel, and stratify fresh plants in it. The fermented plant appears still green, but it has lost three fourths of its bulk in the process, or from 12 to 14 per cent. of its weight, chiefly water and extractive matter.

The liquor in the lower vat must be strongly beaten for an hour and a half, when the indigo begins to agglomerate in flocks, and to precipitate. This is the moment for judging whether any error has been committed in the fermentation; which must be corrected by the operation of beating. If the fermentation has been arrested too soon, much froth rises in the beating, which must be allayed with a little oil, and then a reddish tinge appears. If large round granulations are formed, the beating is continued, in order to see if they will grow smaller. If they become as small as fine sand, and if the water clears up, the indigo is allowed quietly to subside. Should the vat have been over fermented, a thick fat-looking crust covers the liquor, which does not disappear by the introduction of a flask of oil. In such a case the beating must be moderated, and when the granulations become round, and begin to subside, and the liquor clears up, the beating must be discontinued. When the fermentation has been excessive, the froth or scum diffuses itself spontaneously into separate minute particles, that move about the surface of the liquor. On the other hand, a rightly fermented vat is easy to work; the froth, though abundant, vanishing whenever the granulations make their appearance. The colour of the liquor, when drawn out of the steeper into the beater, is bright green; but as soon as the agglomeration of the indigo commences, it assumes the colour of Madeira wine; and speedily afterwards, in the course of beating, a small round grain is formed, which falls down and leaves the water transparent, when all the turbidity and froth vanish.

The object of the beating is threefold: first, it tends to disengage a great quantity of carbonic acid present in the fermented liquor; secondly, to give the newly developed indigo its requisite dose of oxygen by the most extensive exposure of its particles to the atmosphere; thirdly, to agglomerate the indigo in distinct flocks or granulations. In order to hasten the precipitation, lime water is occasionally added to the fermented liquor in the progress of beating; but those who manufacture the superior qualities of indigo, avoid the use of lime, as it has a tendency to make the indigo hard and red. In one side of the beating vessel a beam is fixed upright, in which three or more holes are pierced a few inches in diameter. These are closed with plugs during the beating, but, two or three hours afterwards, as the indigo subsides, the upper plug is withdrawn to run off the supernatant liquor, and then the lower plugs in succession. The state of this liquor affords, on being examined, an indication of the success of both the processes. When the whole liquor has run off, a labourer enters the vat, sweeps all the precipitate into one corner, and empties the thinner part into a spout which leads into a cistern, 20 feet long, 3 feet wide and 3 feet deep. When all this liquor is once collected, it is pumped through a bag

which retains the impurities into a boiler, placed at the side of the cistern and heated to ebullition. The froth soon subsides, leaving an oily looking film upon the liquor. The indigo is by this process not only freed from the yellow extractive matter, but its density and the intensity of its colour are increased. From the boiler the mixture is run, after two or three hours into a general receiver, called the *dripping vat* or table, which, for a factory of twelve pairs of preparation vats, is 20 feet long, 10 feet wide, and 3 feet deep having a false bottom, 2 feet under the top edge. The cistern stands in a basin of masonry (made water-tight with Chunam hydraulic cement), the bottom of which slopes to one end, in order to facilitate the drainage. A thick woollen web is stretched along the bottom of the inner vessel to act as a filter; but a piece of cotton cloth is generally preferred to wool, as the hairs which are detached from the latter injure the quality of the indigo. As long as the liquor passes through turbid, it is pumped back into the receiver. Whenever it runs clear, the receiver is covered with another piece of cloth to exclude the dust, and allowed to drain at its leisure. Next morning the drained magma is put into a strong bag and squeezed in a press. The indigo is then carefully taken out of the bag, and cut with brass wire into cubical pieces, measuring about 3 inches each way, which are dried in an airy house upon shelves of wicker work. During the drying, a whitish efflorescence appears upon the pieces, which must be carefully removed with a brush. In some places, particularly on the coast of Coromandel, the dried indigo lumps are allowed to effloresce in a cask for some time, and when they become hard they are wiped and packed for exportation.

From some experiments it would appear that the gas disengaged during the middle period of the fermentation is composed in 100 parts of 27·5 carbonic acid, 5·8 oxygen, and 66·7 nitrogen; and towards its conclusion, of 40·5 carbonic acid 4·5 oxygen, and 55·0 nitrogen. Carburetted hydrogen does not seem to be disengaged. That the liquor in the beating vat absorbs oxygen from the air in proportion as the indigo becomes flocculent and granular, has been ascertained by experiment, as well as that sunshine accelerates the separation of the indigo-blue. Out of 1000 parts of the fermented liquor of specific gravity 1·003, the blue precipitate may constitute 0·75 of a part. Such a proportion upon the great scale, is however, above the average, which is not more than 0·5. When lime water is added, an extractive matter is thrown down, which amounts to from 20 to 47 parts in 1000 of the liquor. It has a dark brown tint, a viscid appearance, an unpleasant smell, and a bitter taste. It becomes moist in damp air, and dissolves in water without decomposition. It is precipitated by lime, alkalies, infusion of galls, and acetate of lead. All indigo contains a little lime derived from the plant, even though none has been used in its preparation.

2. *Indigo from dried leaves.*—The ripe plant being cropped, is to be dried in sunshine from 9 o'clock in the morning till 4 in the afternoon, during two days, and threshed to separate the stems from the leaves, which are then stored up in magazines until a sufficient quantity is collected for manufacturing operations. The newly dried leaves must be free from spots, and friable between the fingers. When kept dry, the leaves undergo in the course of four weeks, a material change, their beautiful green tint turning into a pale bluish-grey, previous to which the leaves afford no indigo by maceration in water, but subsequently a large quantity. Afterwards the product becomes less considerable.

According to some manufacturers, the plants should be cut down in dry weather, an hour or two before sunset, carried off the field in bundles, and immediately spread upon a dry floor. Next morning the reaping is resumed for an hour and a half, before the sun acts too powerfully upon vegetation, and the plants are treated in the same way. Both cuttings become sufficiently dry by 3 o'clock in the afternoon, so as to permit the leaves to be separated from the stems by threshing. They are now throughly dried in the sunshine, then coarsely bruised, or sometimes ground to powder in a mill, and packed up for the operations of manufacture.

The following process is pursued to extract indigo from the dried leaves. They are infused in the steeping vat with six times their bulk of water, and allowed to macerate for two hours with continual stirring till all the floating leaves sink. The fine green liquor is then drawn of into the beating vat, for if it stood longer in the steeper, some of the indigo would settle among the leaves and be lost. Hot water, as employed by some manufacturers, is not necessary. The process with dry leaves possesses this advantage, that a provision of the plant may be made at the most suitable times, independently of the vicissitudes of the weather, and the indigo may be uniformly made; and moreover, the fermentation of the fresh leaves, often capricious in its course, is superseded by a much shorter period of simple maceration.

We are indebted to Dr. Roxburgh, for a description of the method employed for

manufacturing indigo from the *Nerium tinctorium* or *Wrightia tinctoria*. (Vide Transactions of the Society of Arts, vol. xxviii.) This plant, which attains the size of a small tree, is found on the lower regions of the mountainous tract near Rajamundry, and also on hills in the neighbourhood of Salem and Pondicherry, and grows in a sterile as well as rich soil. The leaves begin to appear in March and April, and at the end of April have attained their full size, when they are ready for gathering. At the end of August they begin to assume a yellowish rusty colour and soon fall off. The leaves yield no indigo until the plant is several years old, but the best leaves for making indigo are obtained from low bushy plants. They improve when kept for a day or two, but when they begin to wither, they yield but a small portion of very bad indigo, and when quite dry only a dirty brown fecula. In this they differ from the leaves of the common indigo plant, which may be dried before extraction without loss of colour. They also differ from the latter in not yielding their colour to cold water. With cold water only a hard, black, flinty substance is obtained, not blue indigo. It is therefore necessary to employ hot water, which extracts the colour very readily. The leaves having been collected, are on the ensuing day thrown into copper scalding vessels, which are then filled with cold water to within 2 or 3 inches of the top. Hard water containing a large quantity of bicarbonate of lime is better adapted for the purpose than rain water. The fire is then lighted and maintained rather briskly until the liquor acquires a deep green colour. The leaves then begin to assume a yellowish colour, the heat of the liquor being about 150° to 160° Fahr. The fire is then removed and the liquor run off into the beating vat. Here it is agitated from 5 to 20 minutes. It is then mixed with about $\frac{1}{70}$ to $\frac{1}{100}$th part of lime water, which produces a speedy granulation. After the indigo has subsided the supernatant liquid appears of a clear Madeira wine colour. The quantity of indigo obtained, amounts to 1 lb. from 250 lbs. of green leaves; but it varies according to the season and the state of the weather. In August and September, the produce is only one-half or two-thirds of what it is in May and June, and even that is diminished if the weather is wet, or the leaves are treated immediately after being gathered. The scalding requires about three hours, and the agitation and precipitation the same time. The indigo is improved by treating it with a little sulphuric acid. The only fault it has is, that it breaks into small pieces, unless it has been dried slowly in the shade protected from the sun.

In the southern provinces of China a species of *Indigofera* is extensively cultivated for the sake of the dye which it affords. In the northern provinces two other plants are employed by the inhabitants for the same purpose. Mr. Fortune, the well-known Chinese traveller, to whom we owe the description of these plants and of the process of manufacturing indigo from them, states that one of them is grown in the neighbourhood of Shanghae, and he has given it the name of *Isatis indigotica*. The other, which is a species of *Justicia*, is largely cultivated in the hilly country near Ningpo, or rather in the valleys among the hills. It seems to be easily cultivated; it grows most luxuriantly, and is no doubt very productive. Having evidently been introduced from a more southern latitude, it is not hardy in the province of Chekiang any more than cotton is about Shanghae; but nevertheless it succeeds admirably as a summer crop. It is planted at the end of April or beginning of May, after the spring frosts are over, and it is cleared from the ground in October. During this period it attains a height of a foot or a foot and a half, becomes very bushy, and is densely covered with large green leaves. It is cut before any flowers are formed. The plants are grown, not from seed but from cuttings. These cuttings consist simply of a portion of the stems of the previous year, which after being stripped of their leaves are tied into bundles, each containing upwards of 1000, and kept during the winter in a dry shed or outhouse, where after being firmly packed together they are banked round with dry loam, and covered with straw or litter so as to protect them from the frost. During the winter months the cuttings remain green and plump, and although no leaves are produced a few roots are generally found to be formed or in the act of forming when the winter has passed and the season for planting has come round. In this state they are taken to the fields and planted. The weather during the planting season is generally showery, as this happens about the change of the monsoon when the air is charged with moisture. A few days of this warm showery weather is sufficient to establish the new crop, which now goes on growing with luxuriance and requires little attention during the summer, indeed none except keeping the land free from weeds. In the country where this dye is manufactured there are numerous pits or tanks on the edges of the fields. They are usually circular in form and have a diameter of about 11 feet and a depth of 2 feet. About 400 catties* of stems and leaves are thrown into a tank of this size, which is

* A Chinese catty is equal to 1⅓lb.

then filled to the brim with clear water. In five days the plant is partially decomposed, and the water has become yellowish-green in colour. At this period the whole of the stems and leaves are removed from the tank with a flatheaded broom made of bamboo twigs. When every particle has been removed, the workmen employed give the water a circular and rapid motion with the brooms just noticed, which is continued for some time. During this part of the operation another man has employed himself in mixing about thirty catties of lime with water, which water has been taken out of the tank for the purpose. This is now thrown into the tank, and the rapid circular motion of the water is kept up for a few minutes longer. When the lime and water have been well mixed in this way the circular motion is allowed to cease. Four men now station themselves round the tank and commence beating the water with bamboo rakes made for this purpose. The beating process is a very gentle one. As it goes on, the water gradually changes from a greenish hue to a dingy yellow, while the froth becomes of a beautiful bright blue. During the process the head workman takes a pailful of the liquid out of the tank and beats it rapidly with his hand. Under this operation it changes colour at once, and its value is judged of by the hue it presents. The beating process generally lasts for about half an hour. At the end of this time the whole of the surface of the liquid is covered with a thick coating of froth of the most brilliant colours, in which blue predominates, especially near the edges. At this stage, it being desirable to incorporate the froth with the liquid below it, it is only necessary to throw a small quantity of cabbage oil on the surface of the froth. The workmen then stir and beat it gently with their flat brooms for a second or two, and the whole instantly disappears. The liquid, which is now darker in colour, is allowed to repose for some hours, until the colouring matter has sunk to the lower stratum, when about two thirds of the liquid is drawn off and thrown away. The remaining third part is then drawn into a small square tank on a lower level, which is thatched over with straw, and here it remains for three or four days. By this time the colouring matter has separated itself from the water, which is now entirely drained off, the dye occupying three or four inches of the bottom in the form of a thick paste and of a beautiful blue colour. In this state it is packed in baskets and exposed for sale in all the country towns in this part of China. Like the Shanghae indigo, made from *Isatis indigotica*, it is called "*Tien-ching*" by the Chinese.—*Gardner's Chronicle and Agricultural Gazette*, April 8th, 1854.

The cultivation of indigo in Central America, has fallen off very much of late years. Nicaragua formerly exported annually about 5000 bales of 150 lbs. each. At present the export probably does not exceed 1000 or 2000 bales. Under the government of Spain, the state of San Salvador produced from 8000 to 10,000 bales annually. A piece of ground equal to two acres generally produces from 100 to 120 lbs. at a cost of not far from 30 to 40 dollars.

There is an indigenous biennial plant abounding in many parts of central America, which produces indigo of a very superior quality, but gives less than half the weight which is afforded by the cultivated species. The *Indigofera disperma* is the species employed in cultivation. It attains its highest perfection in the richest soils. It will grow, however, upon almost any soil, and is very little affected by drought or by superabundant rains. In planting it, the ground is perfectly cleared, usually burnt over, and divided with an implement resembling a hoe into little trenches, 2 or 3 inches in depth, and 12 or 14 apart, at the bottom of which the seeds are strewn by hand, and lightly covered with earth. A bushel of seed answers for 4 or 5 acres of land. In Nicaragua it is usually planted towards the close of the dry season in April or May, and attains its perfection for the purpose of manufacture in from two and a half to three months. During this time it requires to be carefully weeded, to prevent any mixture of herbs, which would injure the quality of the indigo. When it becomes covered with a kind of greenish farina, it is in a fit state to be cut. This is done with knives at a little distance above the root, so as to leave some of the branches, called in the West Indies "ratoons," for a second growth, which is also in readiness to be cut, in from six to eight weeks after. The crop of the first year is usually small, that of the second is esteemed the best, although that of the third is hardly inferior. It is said that some fields have been gathered for ten consecutive years without being re-sown, the fallen seed obviating the necessity of new plantings.

After the plant is cut, it is bound in little bundles, carried to the vat, and placed in layers in the upper or larger one called the steeper (*mojadora*). This vat holds from 1000 to 10,000 gallons, according to the requirements of the estate. Boards loaded with weights are then placed upon the plants, and enough water let on to cover the whole, which is now left to steep or ferment. The rapidity of this process depends much upon the state of the weather and the condition of the plant. Sometimes it is accomplished in 6 or 8 hours, but generally requires from 15 to 20. The proper length

of time is determined by the colour of the saturated water; but the great secret is to check the fermentation at the proper point, for upon this, in a great degree, depends the quality of the product. Without disturbing the plant, the water is now drawn off by cocks into the lower vat or "beater" (*golpeadoro*), where it is strongly and incessantly beaten, in the smaller estates with paddles by hand, in the larger by wheels turned by horse or water power. This is continued until it changes from the green colour, which it at first displays, to a blue, and until the colouring matter, or flocculæ, shows a disposition to curdle or subside. This is sometimes hastened by the infusion of certain herbs. It is then allowed to settle, and the water is carefully drawn off. The pulp granulates, at which time it resembles a fine soft clay; after which it is put into bags to drain, and then spread on cloths in the sun to dry. When properly dried, it is carefully selected according to its quality, and packed in hide cases, 150 lbs. each, called *serons*. The quality has not less than 9 gradations, the best being of the highest figure. From 6 to 9 are called *flores*, and are the best; from 3 to 6 *cortes*: from 1 to 3, inclusive, *cobres*. The two poorer qualities do not pay expenses. A *manana* of 100 yards square produces on an average about one ceroon at each cutting. After the plant has passed through the vat, it is required by law that it shall be dried and burnt; because in decomposing it generates by the million an annoying insect called the "indigo fly."

The following account of the manufacture of indigo on the Senegal is taken from Perottet's "Art de l'Indigotier":—

The land destined to the cultivation of the plant ought to be perfectly level and free from undulations, so as to prevent the seed from being washed into the hollows or lower parts by the heavy rains so frequent in the tropics. Soils of a greyish colour abounding in clay are not adapted for the purpose, as they are too compact and cold. Sandy soils of a whitish colour must also be avoided. Light soils, abounding in humus or vegetable remains, and having a colour between grey and dark brown, are to be preferred to all others. The soil should, at all events, not be one very retentive of moisture. The quantity of indigo obtained from the same weight of plant may vary, according to the soil, from 4 lbs. to 10 lbs., and the quality also varies in a corresponding degree. The extent of ground which is required for the production of indigo on a large scale is so great that the use of manure becomes almost impossible. Nevertheless the employment of the refuse of the plant, after the extraction of the indigo, as a manure on fresh plantations, is found to be attended with very beneficial results. The ground, if new, must be turned up by means of a plough or hoe, to the depth of at least 10 or 12 inches, three times successively at intervals of 3 months, before the sowing takes place. The sowing must only be undertaken in fine weather, never during heavy rain. The seed employed should be perfectly ripe, and, if possible, not more than one year old. It is to be left in the seed-vessels in which it is contained until the time when it is wanted. The latter are then put into a wooden mortar and reduced to fragments, and the seed is separated by winnowing from the dust, débris, &c., with which it is mixed. The sowing is to be effected broad-cast and as evenly as possible. It should take place, if possible, just before the approach of rain, in which case the use of a harrow is not required, as the rain generally has the effect of completely levelling the ground and covering up the seed with soil. The *Indigofera tinctoria*, and its varieties *macrocarpa* and *emarginata*, being a plant with numerous crowded branches, it is not necessary, in sowing it, to take more than from 6 to 7½ kilogrs. of seed to 1 arpent of ground; but the *Indigofera anil*, being more sparingly branched, and therefore taking up less room, requires to be more thickly sown. At about ten or twelve days after sowing, when the young indigoferæ have attained a height of about 81 to 108 millimètres, the ground must be carefully weeded, and this operation must be repeated as soon as the weeds have again made their appearance and commenced to interfere with the growth of the crop. When the season is favourable three months are generally sufficient to enable the plants to attain the degree of development necessary for the production of indigo. At the period when inflorescence commences the plant is far richer in colouring matter than at any other. As soon, therefore, as there are any indications of flowering, and when the lower leaves, in the axils of which the flowers appear, begin to acquire a yellowish tint, and when pressed in the hands produce a slight crackling noise, no time must be lost in cutting down the plant. This is effected by means of good knives or sickles, and as near the ground as possible. The stems, after being cut, are tied together into bundles or sheaves and carried to the manufactory. Since the colouring principle of the indigoferæ is extremely susceptible of change by the action of destructive agencies, it is necessary to use the utmost despatch in gathering the crop, and to have the manufactory of such a size in proportion to the plantation, that no time may be lost in working up the material as soon as gathered. The plants must on no account be cut when they are moistened either with rain or dew, because in this case they acquire a blackish

tint in consequence of the friction to which they are exposed in cutting them and taking them to the manufactory, this tint being a sign of the disappearance of the colouring matter. Besides this, it has been observed that during the continuance of rain the indigo-producing principle diminishes very considerably, and sometimes even disappears entirely, so that, if cut during or immediately after rain, the plants yield little or no indigo. The indigo plant is subject to the attack of a green caterpillar, which sometimes appears in such quantities as to destroy the whole crop. No certain and easy means of destroying this pest is known. It has been recommended to pass wooden rollers over the ground, before the plants have attained any great size, so as to crush the caterpillars without injuring the plants, and this plan has been attended with partial success.

In order to obtain good results in the manufacture of indigo, it is necessary that the plants should be of the same age, of the same species, and from the same field. The *Indigofera anil* begins to ferment several hours sooner than the *I. tinctoria*, so that if a mixture of both be taken, the produce from either one or the other will be lost, and the indigo obtained will also be of a bad quality. The plants should, as soon as possible after being gathered, be placed in the steeping vat, which is a vessel built of bricks, and well lined with cement, from 3½ to 8 metres in length, of the same width, and about 1 metre deep. In this vessel the plants are arranged in successive layers, the lower layers being slightly inclined towards one end, in order to facilitate the subsequent running off of the liquor. The vessel being full, a number of poles of fir-wood are laid lengthways over the plants, at a distance of 162 mill. from one another. Three beams are then laid crosswise over the poles, their ends being well secured by passing them through slits which are cut in the upright posts at the sides of the cistern, and then fixing them by means of iron pins, passing through holes in the posts. By this means the plants are prevented from rising above the surface of the liquor during the process of maceration. The vat is now filled with water from an adjacent cistern, in which it has been allowed to stand for 24 hours for the purpose of allowing all foreign matters contained in it to be deposited. After standing in contact with the leaves for about 6 hours, a change usually begins to manifest itself in the liquor, which must therefore, from that time forward, be carefully watched. As soon as this liquor begins to acquire a green colour, and when a little of it on being kept for a short time in the mouth, leaves a slight impression of harshness (*âpreté*) on the tongue and the palate, it is a sign that the maceration is complete, and that the liquor should be drawn off without delay. If this be not done, the colour of the liquor changes from green to brown, a new species of fermentation commences, accompanied by the formation of acetic acid, and the plant begins to yield substances of a mucilaginous nature, which contaminate the indigo, and completely spoil its quality. It is therefore of the greatest importance to ascertain exactly when the maceration of the plant is complete. The following are the chief indications of this point having been attained :—1. When the water which was at first clear begins to become muddy and acquire a slight greenish tinge. 2. When bubbles of a greenish colour rise to the surface here and there. 3. When towards the edge of the vat some mucilage, or a kind of greyish scum, commences to be formed. 4. When a very slight purple pellicle is observed on the surface of the liquor, especially near the corners of the vat. 5. When the liquor begins to exhale a slight but not disagreeable odour of herbs. When the fermentation has proceeded too far, the following phenomena present themselves :—1. A considerable quantity of large bubbles of air are disengaged, which burst at the surface, forming a layer of greyish mucilage. 2. The surface of the liquor becomes covered with a copper-coloured pellicle. 3. A heaving of the liquor in the vat is observed, giving rise to the disengagement of large greenish bubbles which communicate a brownish colour to the water. 4. The liquor acquires a fetid smell, a strongly acid taste, and a soapy appearance. These phenomena manifest themselves when the weather is hot, after the fermentation has continued about 12 or 14 hours. It then becomes impossible to obtain indigo of good quality, the only product being a black matter resembling wax.

The liquor is now run off from the steeping vat into the beater, which is a cistern of about the same dimensions as the former, but situated at a rather lower level. Here it is subjected to the beating process, the object of which is to expose the reduced indigo to the oxygen of the atmosphere, as well as to promote the disengagement of the carbonic acid gas with which the liquid is charged, and which prevents the precipitation of the indigo. The beating is performed by men, who, provided with paddles, agitate the liquid rapidly, so as to bring every part of it successively into contact with the air. It is of importance that this process should be broken off at the right moment, for if it be continued too long, the grain formed at first will redissolve and be lost. And if, on the other hand, it be arrested before the proper time has arrived, a portion of the indigo will remain unprecipitated. In order to ascertain in

what state the liquor is, a little of it must be poured into a drinking glass and mixed with an equal volume of clear water. If there is formed round the circumference of the glass a line of a bluish-green colour, the beating must be continued; but if on the contrary the liquid appears of a uniform brown colour, and if on adding to it a few drops of clear lime water with the finger the indigo precipitates immediately in grains, the process must be arrested. The beating usually occupies from an hour and a half to two hours. The liquid is now to be well mixed with about $\frac{1}{10}$th of its volume of clear lime water, and allowed to rest until the indigo has quite settled. By opening successively the plugs which are placed at different heights in the side of the vessel, the clear liquor is then drawn off in separate portions and permitted to run away, care being taken that none of the indigo is allowed to be carried away with the water. By means of an opening situated near the bottom of the beating vat the indigo mixed with water is then run off, and flowing through a canal is received on a cloth strainer or filter. This filter rests on a round or four-cornered vessel, the top of which is on a level with the surface of the ground, and which is called the *diablotin*. When the liquid has run through the filter, the indigo which remains behind in a state of paste is mixed up again with water, and the mixture is poured on a canvas filter and allowed to run immediately into the boiler. The refuse matter, consisting of leaves of the plant, &c., remains on the canvas, while the indigo suspended in water runs through. The boiler is a vessel with sides of masonry, and a bottom consisting of a copper plate which rests on iron bars, and is well cemented to the sides. Underneath the copper plate is the fire-place. The top must be covered with a wooden lid, consisting of two flaps which are fixed to hinges at the sides and meet together over the top. At the moment when the mixture of indigo and water is introduced into the boiler, the latter must already be about one third full of hot water, the mixture being sufficient almost to fill it entirely. The heat is now raised gradually to the boiling point, and the boiling is continued for about two hours. In order to prevent the indigo from adhering to the bottom and sides of the boiler, the liquor must be kept continually stirred with a wooden rake. The object of the boiling is to drive away all the carbonic acid that may still be present in the liquor, to remove the soluble extractive matters which would render the indigo dull and impure, to prevent the fermentation or putrefaction of the indigo which would otherwise take place, and lastly, to facilitate the subsequent processes of filtering and pressing. The fire having been removed, the liquor is allowed to stand for some time, and as soon as the indigo has settled, the supernatant liquid is drawn off by means of taps fixed in one of the sides of the boiler. The lowest tap is then opened, and the indigo is run off with the water and received on a filter, consisting of blue Guinea cloth stretched on a frame. The first portions of liquid which run through are usually coloured with indigo, and must therefore be caught in a suitable vessel and poured on the filter again. As soon as the liquid has percolated, the indigo, which is now a compact paste, is removed from the filter by means of a wooden ladle and put into a press, which consists of a wooden box pierced with holes. The press having been lined with cloth, the indigo is put in, the cloth is folded round it as evenly as possible, a wooden lid is dropped on the cloth, and the mass is submitted to pressure by means of a screw, until no more liquid runs through at the bottom, which takes place as soon as the indigo has been reduced to about a third of its original volume. The press is then opened, the indigo is taken out of the cloth, laid on a table and divided by means of a knife into pieces of a cubical shape. These cubes are then taken to the drying shed, where they are placed on trellises covered with matting or very thin cloth, so as to admit of the free passage of air. Care must be taken not to dry them too rapidly, otherwise the cakes would crack and split into fragments, which are then of little commercial value, and it is therefore necessary to protect them from currents of dry air by covering them with canvas or Guinea cloth. During the drying process, which occupies from 8 to 10 days, the cakes should be turned several times. They are then closely packed in boxes, each box holding about 25 kilogrammes. The boxes should be lined with paper.

It may be remarked, that when the indigo is of good quality, the volume of the paste diminishes very little when subjected to pressure. If the process of filtering takes up much time and the pressing is attended with difficulty, it may be anticipated that the indigo will turn out of bad quality. This may proceed from the plant having been overgrown, or from the maceration or the beating process having been continued too long, or from the employment of too large a quantity of lime water. The difficulty experienced in pressing the indigo paste, and which is often so great as to cause the cloth in which it is enveloped to break, is caused by the presence of a mucilaginous or viscous substance mixed with the indigo, which may be removed by treating the paste again with boiling water, and repeating the operations of filtering and pressing.

In regard to the state in which indigo exists in the plants from which it is derived, and the nature of the process by which it is obtained, various opinions have been

entertained by chemists. Berthollet in his work on dyeing says, "that the three parts of the process employed have each a different object. In the first a fermentation is excited, in which the action of the atmospheric air does not intervene, since an inflammable gas is evolved. There probably results from it some change in the composition of the colouring particles themselves; but especially the separation or destruction of a yellowish substance, which gave to the indigo a greenish tint, and rendered it susceptible of undergoing the chemical action of other substances. This species of fermentation passes into a destructive putrefaction, because the indigo has a composition analogous to that of animal substances. Hitherto the colouring particles have preserved their liquidity. In the second operation, the action of the air is brought into play, which, by combining with the colouring particles, deprives them of their solubility, and gives them the blue colour. The beating serves, at the same time, to dissipate the carbonic acid which is formed in the first operation, and which by its action presents an obstacle to the combination of the oxygen. The separation of this acid is promoted by the addition of lime; but if an excess be introduced, it counteracts the free combination of the oxygen. The third part of the process has for its objects: the deposition of the colouring matter, become insoluble by combination with oxygen, its separation from foreign substances, and its desiccation, which gives it more or less hardness, whence its appearance varies." De Cossigny was of opinion that volatile alkali was the agent by which the colouring matter was extracted from the plant and held in solution until volatilised by the agitation process. Roxburgh concluded from his experiments, "that the indigo plants contain only the base of the colour, which is naturally green; that much carbonic acid is disengaged during its extrication from the leaves; that the carbonic acid is the agent whereby it is probably extracted and kept dissolved; that ammonia is not formed during the process; that the use of the alkalies employed is to destroy the attraction between the base and the carbonic acid; and that the vegetable base being thereby set at liberty, combines with some colouring principle from the atmosphere, forming therewith a coloured insoluble fecula, which falls to the bottom and constitutes indigo."

Chevreul, who was the first chemist of any eminence to examine the indigo-bearing plants and their constituents, inferred from his analyses of the *Isatis tinctoria* and the *Indigofera anil*, that these plants contain indigo in the white or reduced state, in the same state in which it exists in the indigo vat; that in this state it is held in solution by the vegetable juices, and that when the solution is removed from the plant, it is converted by the action of the atmospheric oxygen into indigo-blue. Giobert, from an examination of the *Isatis tinctoria*, drew the following conclusions: — 1. Indigo-blue does not pre-exist in the plant, but is formed during the operations by means of which we believe it to be extracted. 2. There exists in a small number of plants a peculiar principle, different from all the known proximate constituents of plants, and which has the property of being convertible into indigo; this principle may be called *indigogene*. 3. This principle differs from indigo in containing an excess of carbon, of which it loses a portion, in passing into the state of indigo-blue, by the action of a small quantity of oxygen which it takes up. 4. The loss of this portion of carbon must be attributed to its undergoing combustion, and being converted into carbonic acid. 5. It differs in its properties from common indigo in being colourless and soluble in water, and by its greater combustibility, which causes it to undergo spontaneous combustion at the ordinary temperature of the atmosphere. 6. Its combustibility is enhanced by heat and by combination with alkalies, especially lime; it is diminished by the action of all acids, even carbonic acid. About the year 1839, the *Pylogonum tinctorium*, an indigo-bearing plant indigenous to China, became the subject of a series of investigations by several French chemists, chiefly with a view to ascertain whether this plant, if grown in France, could be advantageously employed in the preparation of a dyeing material as a substitute for foreign indigo. Baudrimont and Pelletier, after an examination of this plant, arrived at the conclusion that the indigo is contained in it as reduced indigo, in the same state as it is in woad, according to Chevreul. Robiquet, Colin, Turpin, and Joly, on the other hand, expressed a very decided conviction that indigo-blue pre-exists in the plant, but not in a free state; that it is combined with some organic substance or substances, which render it soluble in water, ether and alcohol; and that the operation of potent agencies is requisite in order to destroy this combination and set the indigo at liberty. The explanation of Chevreul, proceeding from an authority of such eminence, and being the simplest, has been adopted by most chemists. Nevertheless there are objections to it which render it inadmissible. Reduced indigo is a body which is only soluble in alkalies, and cannot, therefore, be contained as such in the juice of indigo plants, which is mostly acid. As it also takes up oxygen with the greatest avidity, and is converted into indigo-blue, it is difficult to conceive how the whole of it can be preserved in a colourless state in the cells of plants, in which it must occasionally come in contact

with the oxygen eliminated by the vegetable organism. If these plants contained reduced indigo, the juice ought, moreover, to turn blue the moment it became exposed to the atmosphere, which is not always the case. The necessity for a long process of fermentation in order to obtain the colouring matter would also not be very apparent, the mere contact with oxygen being, it might be supposed, all that was necessary for the purpose. The facility with which the indigo-blue is destroyed if the process of fermentation is carried too far, is also inconsistent with the supposition that it is contained in plants either as such, or in a de-oxidised state, since indigo-blue is a body not easily decomposed, except by very powerful agents.

In order to throw some light on this subject, an investigation was undertaken by Schunck into the state in which indigo-blue exists in the *Isatis tinctoria*, or common woad, which is the only plant indigenous to Europe that yields any considerable quantity of the colouring matter. Schunck succeeded in obtaining from that plant a substance of very peculiar properties, to which he gave the name of *Indican*. This substance has the appearance of a yellow or light brown transparent syrup. It has a bitter taste. It is very easily soluble in water, alcohol, and ether; its solutions are yellow and have an acid reaction. Its compounds with bases are yellow. When its watery solution is mixed with a strong acid, such as muriatic or sulphuric acid, no change takes place at first, but on leaving the solution to stand, or on heating it, it becomes blue and opalescent, then acquires a purple colour, and at length deposits a quantity of purplish-blue flocks, which are quite insoluble in water. These flocks consist for the most part of indigo-blue, but they contain also a red colouring matter and several brown substances of a resinous nature. The supernatant liquid contains a peculiar kind of sugar, and on being distilled, yields carbonic, formic, and acetic acids. Hence it follows that the plant does not contain indigo-blue ready formed either in the blue or colourless state, that the latter exists in the vegetable juice in a state of combination with sugar, forming a compound of that peculiar class known to chemists as *glucosides*. This compound is readily dissolved by water, and the indigo-blue may then be liberated and precipitated from the solution by means of acids, and probably also by other agents, but the simultaneous action of oxygen is not necessary during the process of decomposition, which the compound undergoes in yielding indigo-blue. Now if, as seems probable, the various species of indigofera contain indican or some similar substance, the phenomena which take place during the process of manufacturing indigo may easily be explained. During the steeping process the indican is dissolved, and in consequence of the fermentation which then takes place in the liquor it is decomposed into indigo-blue and sugar. The former would then be precipitated, but since ammonia is, according to most authors, evolved at the same time, the indigo-blue is, by the simultaneous action of the alkali and the sugar, or other organic matters contained in the liquid, reduced and dissolved, forming a true indigo vat, from which the colouring matter is afterwards precipitated by the combined action of the atmospheric oxygen and the lime, during the beating process. According to Schunck, two distinct periods may be observed in the decomposition of indican. During the first period, indigo-blue is the chief product of decomposition; during the second, the red and brown resinous matters make their appearance with very little indigo-blue. The formation of carbonic, acetic, and formic acids is, according to Schunck, dependent on that of the brown resinous matters. It would appear, therefore, that the copious disengagement of carbonic acid, as well as the acid taste, attributed to acetic acid, sometimes observed during the manufacture of indigo, are phenomena which indicate the formation, not of indigo-blue, but of other substances, which may prove very injurious to the quality of the indigo. These substances being soluble in alkalies, but insoluble in water, are precipitated, as soon as the liquid loses the alkaline reaction which it possesses at the commencement, and becomes acid. Though indigo-blue is a body of very stable character, not easily decomposed when once formed, except by potent agencies, still the assertion of Perottet and others, that "nothing is more fugitive and more liable to be acted on by destructive agencies, than the colouring principle of the indigoferæ," will be easily understood when the following facts, mentioned by Schunck, are taken into consideration. If a watery solution of indican, this indigo-producing body, be boiled for some time, it then yields by decomposition, not a trace of indigo-blue, but only indigo-red, and if it be boiled with the addition of alkalies, it then gives neither indigo-blue nor indigo-red, but only the brown resinous matters before mentioned. The mere action of alkalies is therefore sufficient to cause the molecules, which would otherwise have gone to form indigo-blue, to arrange themselves in a totally different manner and yield products which bear very little resemblance to it. It is evident, therefore, that one of the chief objects to be kept in view by the manufacturer of indigo, is the proper regulation of the process of fermentation, so as to prevent the formation of the other products, which take the place of indigo-blue, and are formed at its expense.

The indigo of commerce occurs in pieces, which are sometimes cubical, sometimes of an irregular form. These pieces are firm and dry, and are easily broken, the fracture being dull and earthy. It is sometimes lighter, sometimes *apparently* heavier than water, this difference depending on its being more or less free from foreign impurities, as well as upon the treatment of its paste in the boiling, pressing, and drying operations. Its colour is blue of different shades; as light-blue, purplish-blue, coppery-blue, and blackish-blue. On being rubbed with the nail, or a smooth hard body, it assumes the lustre and hue of copper. It is usually a homogeneous mass, but it occasionally contains grains of sand or other foreign bodies, and sometimes presents inequalities of colour. It is frequently full of small cavities, which proceeds from the drying process having been conducted too rapidly, and it is also covered at times with a whitish matter consisting of mould. It varies very much in consistency, being sometimes dry, hard, and compact, whilst sometimes it is easily broken into thin flat pieces. Indigo is devoid of smell and taste. When applied to the tongue, however, it adheres slightly, in consequence of the property which it possesses of rapidly absorbing moisture, a property which is often had recourse to in order to ascertain its quality. When thrown on red-hot coals it yields vapours of a deep purple colour, which, when condensed on cold bodies, give shining needles having a coppery lustre. It is insoluble in water, cold alcohol, ether, muriatic acid, dilute sulphuric acid, cold ethereal and fat oils; but boiling alcohol and oils dissolve a little of it, which they deposit on cooling. Creosote has the property of dissolving indigo.

Indigo varies very much in quality, but it requires much discrimination in order to judge fairly of the quality of any sample from mere inspection and application of the tests usually employed by dealers. A cake of indigo being broken, and the nail or the edge of a shilling being passed with a tolerable degree of pressure over the fractured part, a fine coppery streak will be produced if the indigo is good. If the indigo furrows up on each side of the nail, it is weak and bad, and if the coppery streak be not very bright it is not considered good. When a piece of indigo is broken the fracture should be held up to the sun, and, if it has not been well strained from the dross, particles of sand will be seen glistening in the sun-light. The outside or coat should also be as free from sand as possible. When the squares are broken in the chests the indigo fetches a low price, and if it is very much crushed it is only bought by the consumers for immediate use. The methods employed for ascertaining the true amount of colouring matter in any sample of indigo will be described below.

Indigo is generally classified according to the various countries from which it is obtained. The principal kinds are the following: — Bengal, Oude, Madras, Manilla, Java, Egyptian, Guatemala, Caraccas, and Mexican.

At the present day the finest qualities of indigo are obtained from Bengal, the produce of that country having now taken the place in public estimation which was once occupied by that of the Spanish colonies. The export of indigo from Bengal, which in 1853 amounted to 120,000 maunds (of 74 lbs. 10 oz.), would require for its culture about 1,025,000 acres, and an annual expenditure of 1,300,000*l*. Of this extent of land about 550,000 acres is believed to be included in the Lower Provinces, and consists chiefly of alluvial land rescued from the rivers. The best qualities of Bengal indigo are manufactured in the Jessore and Kishenaghaur districts, but each district produces a quality peculiar to itself, and differences of a less striking character may be perceived in the produce of different factories. The Bengal indigo, when packed in chests, consists of four principal qualities, viz., the blue, purple, violet, and copper. But these kinds, by passing over into one another, produce a number of intermediate varieties, such as purply blue, blue and violet, purply violet, &c. The various qualities would, therefore, be distinguished as follows: — 1. Blue. 2. Blue and violet. 3. Purple. 4. Purple and violet. 5. Violet. 6. Violet and copper. 7. Copper. The leading London brokers, however, classify Bengal indigo into the following grades: — fine blue, fine purple and violet, fine red and violet, good purple and violet, middling violet, middling defective, consuming fine, middling and good, ordinary, ordinary and lean trash. The finest qualities of Bengal indigo present the following characteristics. They consist of cubical pieces, are light, brittle, of a clean fracture, soft to the touch, of a fine bright blue colour, porous, and adhering to the tongue. The lower qualities have a duller colour, assume more and more of a reddish tinge, are heavier, more compact, and less easily broken.

The indigo from the upper provinces of India comes chiefly from Tyroot, Oude, and Benares. It is inferior to Bengal indigo.

Of Madras indigo there are two kinds, viz.: 1. Dry leaf, made from dry stacked leaves; and 2. Kurpah, which is manufactured from the wet leaf in the same way as Bengal indigo. The latter has only come into use since 1830. Both are of inferior quality to Bengal indigo.

The Manilla indigoes present the marks of the rushes upon which they have been

dried. The pieces are either cubical, or flat and square, or of irregular shape. The quality is very unequal. Java indigo occurs in flat, square, or lozenge-shaped masses, the quality approaching that of Bengal. Both these kinds are consumed chiefly on the continent of Europe.

Guatemala indigo is imported into this country in serons or hide wrappers, each containing about 150 lbs. net. It occurs in small irregular pieces, which are more or less brittle, compact, lighter than water, and of a bright blue colour with an occasional tinge of violet. There are three kinds of Guatemala indigo, viz.: 1. Flores, which is the best, and approaches in quality, that of the finer Bengal indigoes; 2. Sobres; and 3. Cortes, which is the lowest in quality, being heavy, difficult to break, and of a coppery-red colour. Of the first kind very little now reaches the market. The indigo of Caraccas is, generally speaking, inferior to that of Guatemala.

The manufacture of indigo was formerly carried on in St. Domingo, but has for some time been entirely abandoned.

The indigo of commerce, even when not adulterated, is a mixture of different matters. When it is heated in a state of fine powder to 212° F. it loses from 5 to 10 per cent. in weight, the loss consisting of water. When the dry powder is heated in a crucible, a great part of it burns away, and there is left at last a greyish ash, consisting of the carbonates and phosphates of lime and magnesia, sulphate of lime, alumina, oxide of iron, clay, and sand. These matters are partly derived from the plant, partly from the lime and the impurities of the water employed in the manufacture. The quantity of inorganic matter contained in ordinary indigo varies very much. In the better qualities it amounts on an average to about 10 per cent. of the weight; whilst in the inferior qualities, especially of Madras indigo, it often rises to between 30 and 40 per cent. The organic portion of the indigo, or that which is dissipated when indigo is heated, also consists of several different substances.

By treating indigo with various solvents, Berzelius obtained, besides indigo-blue, the true colouring matter of indigo, three other bodies, viz. *indigo-gluten*, *indigo-brown*, and *indigo-red*, which seem to be contained in various proportions in all kinds of indigo. Indigo-gluten is obtained by treating indigo with dilute sulphuric, muriatic, or acetic acid, and then with boiling water. It is left on evaporation of its solutions as a yellow transparent extract, which is soluble in spirits of wine, and easily soluble in water, more difficultly in acid liquids. Its taste is like that of extract of meat. It yields by dry distillation much ammonia and a fetid oil, and behaves in most respects like vegetable gluten. On treating the indigo, after being freed from the indigo-gluten, with hot strong caustic lye, the indigo-brown together with a little indigo-blue dissolves, forming a dark brown, almost black solution, from which the indigo-brown after filtration from the portion insoluble in alkali is precipitated by means of acid. After being purified, indigo-brown has the appearance of a dark brown transparent resin, which is almost tasteless and quite neutral. By dry distillation it affords ammonia and empyreumatic oil. It is decomposed by nitric acid and chlorine. It combines both with acids and bases. Its compounds with alkalies are dark brown, and easily soluble in water. The compound with baryta is not easily soluble in water, and that with lime is insoluble. By boiling the alkaline compounds with lime in excess the indigo-brown may be separated and rendered insoluble. The green substance obtained by Chevreul from indigo seems to have been a compound of indigo-brown with ammonia containing a little indigo-blue, either in a state of combination or mechanically intermingled. Indigo-brown seems to bear a great resemblance in many of its properties to the brown resinous substances obtained by Schunck in the decomposition of indican with acids. From its constant occurrence in all kinds of indigo, it may be inferred that it is not a mere accidental impurity, but stands in some unknown relation to indigo-blue. As long, however, as its origin and composition are unknown, this must remain a mere supposition. After the removal of the indigo-gluten and indigo-brown, the indigo is exhausted with boiling alcohol of specific gravity 0·83. A dark red solution is obtained, which is filtered and distilled, when the indigo-red contained in it is deposited as a blackish-brown powder, which is quite insoluble both in water and in alkaline liquids. Indigo-red, according to Berzelius, is amorphous, but by distillation in vacuo yields a white crystalline sublimate, as well as unchanged indigo-red. Concentrated sulphuric acid dissolves it, forming a dark yellow solution, which deposits nothing on being mixed with water; the diluted solution is rendered colourless by wool, which at the same time acquires a dirty yellowish-brown or red colour. The description given by Berzelius leaves it doubtful whether the indigo-red obtained by him from indigo was a pure unmixed substance. From the leaves of the indigofera, as well as from those of the *Isatis tinctoria*, a substance may, according to Schunck, be extracted which has received from him the name of *indirubine*, but which seems to be merely indigo-red in a state of purity. This substance has, according to Schunck, the following properties: it crystallises in small silky needles of a brownish-purple colour, which when rubbed

with a hard body show a slight bronze-like lustre. When carefully heated it may be entirely volatilised, yielding a yellowish-red vapour, which condenses in the form of long plum-coloured needles, having a slight metallic lustre. It dissolves in concentrated sulphuric acid, forming a solution of a beautiful purple colour, which when diluted with water yields no deposit and then imparts a fine purple colour to cotton, wool, and silk. It is insoluble in water, but dissolves in boiling alcohol with a splendid purple colour. It is insoluble in alkalies, but dissolves when exposed to the combined action of alkalies and reducing agents, just as indigo-blue does, forming a solution from which it is again precipitated on exposure to the oxygen of the atmosphere. This solution dyes cotton purple. In most of its properties this body bears a striking resemblance to indigo-blue, and the composition of the two is identical.

It has been doubted whether these various substances or impurities with which indigo-blue is associated produce any effect in the dyeing process on cotton. In a memoir by Schwarzenberg, to which a prize was awarded by the Société Industrielle de Mulhouse, the author arrives at the conclusion that neither indigo-gluten, indigo-brown, nor indigo-red gives rise to any appreciable effect when added to an indigo vat prepared with pure indigo-blue. Nevertheless differences are observable in dyeing with different kinds of indigo, which can only be explained on the supposition that something besides indigo-blue takes part in the process. In the ordinary blue vat, made with copperas and lime, any effect which might be produced in dyeing, by the indigo-brown is neutralised by the lime, which forms with it an insoluble compound. Indigo-red, however, dissolves, as mentioned above, in contact with alkalies and reducing agents, and the solution imparts a purple colour to cotton. In the ordinary indigo vat its presence may be detected by precipitating a portion of the liquor, and treating the precipitate with boiling alcohol, which then usually acquires a red colour. It is possible, therefore, that a small part of the effect produced in dyeing with indigo may be due to indigo-red.

That portion of the indigo which remains after treatment with acid, alkali, and alcohol consists essentially of indigo-blue, the true colouring matter of indigo, mixed, however, with sand, earthy particles, and other impurities. In order to purify it, the residue, while still moist, is to be mixed with lime, the quantity of which must amount to twice the weight of the crude indigo, and which has been previously slaked with water. The mixture is then put into a bottle capable of holding about 150 times its volume of water, and the bottle is filled up with boiling water and shaken. A quantity of finely powdered protosulphate of iron, amounting to ⅛ of the weight of the lime is then added, the bottle is closed with a stopper, well shaken, and left to stand for several hours in a warm place. The mass gradually becomes green, and the indigo-blue is then converted by the precipitated protoxide of iron into reduced indigo, which dissolves in the excess of lime, forming a deep yellow solution. This solution when clear is poured off from the deposit into a vessel containing a sufficient quantity of dilute muriatic acid to supersaturate the whole of the lime. The reduced indigo which is precipitated in greyish-white flocks, is agitated with water until it has become blue, and the regenerated indigo-blue is collected on a filter and washed with water, in order to remove the chloride of calcium and excess of muriatic acid. The following method of obtaining pure indigo-blue has been recommended by Fritzsche: 4 oz. of crude indigo and the same weight of grape sugar are put into a bottle capable of holding 12 lbs. of water; a solution of 6 oz. of concentrated caustic soda lye in alcohol is then added, after which the bottle is filled with hot spirits of wine of 75 per cent., and the whole is left to itself for some time. The liquid becomes at first wine-red, then yellow, and on being filtered and left exposed to the air, deposits the indigo-blue in small crystalline scales, which are to be filtered off and washed at first with alcohol, and then with water.

Pure indigo-blue has the following properties:—Its colour is dark blue inclining to purple. When rubbed with a hard body it assumes a bright coppery lustre. It has neither taste nor smell, possesses neither acid nor basic properties, and belongs, as regards its chemical affinities, to the class of indifferent substances. Its specific gravity is 1·50. When heated in the open air it melts, boils, and burns with a smoky flame, leaving a carbonaceous residue. But when it is heated in a vessel partially closed, or in vacuo, it begins to evolve at a temperature of about 550° F. a violet coloured vapour, which condenses on the colder parts of the apparatus in the form of long crystalline needles, which are blue by transmitted light, but exhibit by reflected light a beautiful coppery lustre. These needles are unchanged indigo-blue. A great portion of the indigo-blue is however decomposed during the heating process. Indigo-blue is insoluble in water, alkalies, and dilute acids. Boiling alcohol and boiling oil of turpentine dissolve a minute quantity of it, and deposit it again on cooling. Fixed oils also dissolve a little of it at a heat exceeding that of boiling water, yielding blue solutions, the colour of which, when the heat is further increased, changes, according

to Mr. Crum, first to crimson and then to orange. By the action of dilute nitric and chromic acids indigo-blue is decomposed and converted into *isatine*, a body soluble in water and crystallising in red needles. Chlorine also decomposes indigo-blue, changing it into *chlorisatine*, a substance having properties very similar to those of isatine. Both isatine and chlorisatine afford with different reagents a great number of products of decomposition, none of which have, however, as yet found any application in the arts. By the long continued action of boiling nitric acid indigo-blue is converted, first into *indigotic acid*, a white crystalline acid, and then into *nitropicric acid*, which is yellow and crystallised. The latter is sometimes employed for imparting a yellow colour to silk and wool, but it is generally prepared from cheaper materials than indigo-blue. The action of concentrated sulphuric acid on indigo-blue is very remarkable. When the acid is poured on the pure substance and gently heated it acquires in the first instance a green colour, which changes after some time to blue. No gas of any kind is evolved. When however crude indigo is employed, there is a perceptible disengagement of sulphurous acid, resulting from the action of the sulphuric acid on the impurities of the indigo, such as the indigo-gluten, &c. On adding water, a solution of a beautiful deep blue colour is obtained. The filtered liquid contains a peculiar acid, to which the names of *indigo-sulphuric*, *sulphindigotic*, *sulphindylic*, or *cæruleo-sulphuric acid* have been applied.

This acid is a so-called *double acid*. It contains indigo-blue and sulphuric acid, but in such a peculiar state of combination, that neither of the two constituents can be detected by ordinary re-agents, nor again eliminated as such from the compound. It combines with bases, without either of the two constituents separating. The compounds are called *indigo-sulphates*, and are, like the acid, of a dark blue colour. When the solution of indigo-blue in concentrated sulphuric acid is diluted with water, there is usually formed a small quantity of a dark blue flocculent precipitate, which is the *phenicine* of Mr. Crum, or the *indigo-purple* of Berzelius. It is a compound of indigo-blue with sulphuric acid, containing less of the latter than indigo-sulphuric acid. It is always formed when the quantity of sulphuric acid employed is not more than eight times that of the indigo-blue, or when the action of the acid on the latter has continued for only a short time. By heating it with an excess of acid it is changed into indigo-sulphuric acid. Though soluble in concentrated sulphuric acid, it is insoluble in the dilute acid, and hence is precipitated on the addition of water. On filtering and washing, however, it begins to dissolve, as soon as the free sulphuric acid has been removed, and may then be completely dissolved by pure water. The solution has a blue colour, just like that of indigo-sulphuric acid. Its compounds with bases have a blue colour with a purplish tinge. The blue acid liquid filtered from the indigo-purple on being supersaturated with carbonate of potash or soda, deposits a dark blue powder, which consists of the indigo-sulphate of potash or soda. These compounds are insoluble in water containing a large quantity of neutral salts, and are therefore precipitated when the excess of sulphuric acid is neutralised by carbonate of potash or soda. As soon, however, as the sulphate of potash or soda has been removed by washing, the indigo-sulphate may be dissolved in pure water, yielding a dark-blue solution. The indigo-sulphates of the alkalies may also be prepared by steeping wool, previously well cleaned, into the solution in sulphuric acid. The wool takes up the colour, becoming of a dark blue colour, and after having been well washed with water, in order to remove the excess of acid as well as the impurities which are always present in the solution when crude indigo has been employed, is treated with carbonate of potash, soda, or ammonia, which separate the acid from the wool, and produce blue solutions containing the salts of the respective bases. The indigo-sulphates of the earths and metallic oxides, which are mostly insoluble blue powders, may be obtained from the alkaline salts by double decomposition. By an excess of caustic alkali, indigo-sulphuric acid is immediately decomposed, giving a yellow solution, from which it is impossible to obtain the acid again. By means of reducing agents, such as sulphuretted hydrogen, nascent hydrogen, protosalts of tin and iron, &c., indigo-sulphuric acid is decolorised, but the colour is restored by the oxygen of the atmosphere. Indigo-sulphuric acid, in a free state or in combination with alkalies, is employed in the arts for the purpose of imparting a blue colour to silk and wool. It has very little affinity for cotton fibre, but is nevertheless employed occasionally for blueing white cotton-yarn and other bleached goods.

By treatment with strong boiling caustic potash or soda lye, indigo-blue is gradually decomposed and converted into a colourless crystallised acid, *anthranilic acid*. By weak solutions of caustic alkalies, it is not in the least affected. If, however, it be subjected to the combined action of an alkali or alkaline earth and some body having a strong affinity for oxygen, such as protoxide of iron or tin, sulphur, sulphurous or phosphorous acid, or organic matters, such as grape-sugar, &c., it disappears by degrees, yielding a yellow solution, containing in the place of indigo-

blue another substance, which has been called *indigo-white*, *indigogene*, or *reduced indigo*. When an excess of some acid is added to the yellow solution, the indigo-white is precipitated in white or greyish-white flocks, which on filtration and exposure to the atmosphere rapidly become blue, and are reconverted into indigo-blue. Indigo-white is insoluble in water, but slightly soluble in alcohol. It is soluble in caustic alkalies, lime and baryta water. The solutions on exposure to oxygen become covered with a pellicle of regenerated indigo-blue. With an excess of lime it gives an insoluble compound. Its compounds with alumina and metallic oxides, which are insoluble in water, may be obtained by double decomposition. Salts of oxide of copper, when added to its solutions in alkali, convert it immediately into indigo-blue, the oxide of copper being reduced to suboxide. Indigo-blue is also converted into indigo white, when it is exposed to the action of fermenting or putrefying substances, in the presence of water. Here the decomposing organic matter is the reducing agent, and ammonia, which is usually formed during the process of putrefaction, is the solvent of the indigo-white. If a piece of cotton, wool, or silk be dipped into an alkaline solution of indigo-white and then exposed to the atmosphere, it acquires a blue colour, which may be made deeper by repeated dippings, and subsequent exposure. It is on this property of indigo-white that the dyeing with indigo depends.

The true chemical formula of indigo-blue, which was first discovered by Mr. Crum, is $C^{16}H^5NO^2$, and 100 parts contain therefore by calculation 73·28 carbon, 3·81 hydrogen, 10·68 nitrogen, and 12·23 oxygen. The formula of indigo-white is $C^{16}H^6NO^2$, and it differs therefore from indigo-blue by containing 1 atom more of hydrogen, which is taken up during the so-called reduction of the latter, and lost again by oxidation during its reconversion into indigo-blue.

Since the value of indigo depends entirely on the quantity of indigo-blue which it contains, it is of great importance to ascertain the exact amount of the latter in any given sample of the article. Before commencing the determination of the indigo-blue, a weighed portion of the indigo ought to be heated for some hours at 212° F., and then weighed again. The loss in weight which takes place represents the amount of water contained in the sample. A weighed quantity of the dried indigo is then to be heated over the flame of a lamp until all the organic matter has been burnt away. By weighing the residue which is left the amount of ash or inorganic matter is ascertained. In order, in the next place, to determine the amount of indigo-blue, several methods have been devised by various chemists, none of which however yield very accurate results. Of these methods the following are the principal ones:

1. A weighed quantity of finely pounded indigo is rubbed with water in a porcelain mortar. An equal weight of pure lime is then slaked with water and the hydrate is well mixed with the indigo. The mixture is then poured into a stoppered bottle of known capacity, and the mortar is well rinsed with water, which is added to the rest. The bottle is now heated in a water-bath for several hours, and a quantity of finely pounded sulphate of iron is added; the bottle is then filled up with water, the stopper is inserted, and after the contents have been well shaken the whole is allowed to repose for some hours, until the indigo has become reduced and the sediment has sunk to the bottom. A portion of the clear liquor is then drawn off with a siphon, and the quantity of liquid having been accurately measured, it is mixed with an excess of muriatic acid, and the precipitate, after having been oxidised, is collected on a weighed filter and well washed with water. Lastly, the filter with the indigo-blue is dried at 212° F. and weighed, and the weight of the filter having been subtracted from that of the whole, the weight of the indigo-blue is ascertained. Supposing now that the whole quantity of liquid had been 200 measures, that 50 measures had been drawn off yielding 10 grains of indigo-blue, then the sample contained on the whole 40 grains of the latter. For 60 grains of indigo it is necessary to take from 1lb. to 2lbs. of water.

According to Mr. John Dale of Manchester, who has had great experience in the valuation of indigo for practical purposes, this method, though rather long and tedious, still gives more accurate results than any other. The quantity of indigo-blue indicated by it is generally below the actual quantity contained in the sample. According to Berzelius this loss arises from the lime forming an insoluble compound with a portion of the reduced indigo-blue. Mr. Dale, however, is of opinion, that even when every precaution has been taken, a certain loss, proceeding from some hitherto unascertained cause, cannot be avoided. When for instance pure indigo-blue is treated with lime and copperas in the manner just described, the quantity which is again obtained by precipitation from any portion of the liquid is always less than what it should be by calculation, even when no excess of lime has been employed.

2. The second method of determining the indigo-blue is performed as follows. About 15 or 20 grains of pure indigo-blue, obtained by precipitation from an indigo vat, and the same quantity of the indigo to be tested, which must be previously ground

to a fine powder, are weighed off. and each of them is treated with about 12 times its weight of concentrated sulphuric acid in a flask or porcelain basin. After being heated at a temperature of 120° to 140° F. for about 24 hours, and occasionally well agitated, the two liquids are mixed with water, so that the volume of the two shall be exactly equal. Two equal measures of a weak solution of hypochlorite of lime are then taken, and to the first is added a quantity of the solution of pure indigo. The chlorine liberated by the excess of sulphuric acid in the solution destroys the blue colour of the indigo-sulphuric acid. More of the solution must be added until the liquid begins to acquire a greenish tinge, and the number of measures necessary for the purpose is noted. The same experiment is then made with the solution of crude indigo. The quantity of indigo-blue in the latter is of course in inverse ratio to the number of measures which are requisite in order to take up the whole of the chlorine which is liberated. If, for example, the same quantity of hypochlorite of lime decolorises 167 measures of the solution of pure indigo-blue and 204 measures of the solution of crude indigo, then the quantity of indigo-blue contained in 100 parts of the latter is given by the following proportion ; $204 : 167 :: 100 : x = 81{\cdot}8$.

A number of samples of indigo may be tested in this manner at the same time. Care must be taken to prepare a fresh solution of indigo-blue for every series of trials, since this solution undergoes a change on standing, which renders it quite inapplicable as a standard of comparison. It is necessary also to pay great attention at the moment when the greenish colour indicating an excess of the sulphate of indigo begins to appear, for it will often be found that this colour disappears after standing a few minutes, and a fresh quantity of the blue solution must then be added cautiously, until the greenish tinge becomes permanent, even after standing for some time. Modifications of this process have been introduced by various chemists by the use of permanganate of potash, chlorate of potash, or bichromate of potash, in the place of hypochlorite of lime; but as the principle on which the process depends is in each case identical and the modus operandi is almost the same, it will be unnecessary to enter into any minute description of these modifications. The whole method is, however, open to serious objections, and the results which it affords cannot at all be depended on. In the first place, it is difficult to institute a strict comparison between the different shades of colour resulting from the decomposition of the sulphate of indigo in different cases, since the pure green tinge observed when an excess of the pure sulphate has been added to the decomposing agent, gives place to a dirty olive or brownish-green, when a solution of crude indigo is employed, in consequence of the impurities contained in the latter. Secondly, it is almost impossible to avoid the formation of a certain quantity of sulphurous acid during the action of concentrated sulphuric acid on crude indigo. This sulphurous acid during the following operation becomes oxidised before the blue sulphate is destroyed, and hence the percentage of indigo-blue is apparently raised. In employing this method, it is common to find more than 80 per cent. of indigo-blue in a good sample of indigo, whereas the best qualities seldom contain above 60 per cent., and average qualities between 40 and 50 per cent. This method may show a percentage of 70 indigo-blue, when the method first described indicates between 50 and 60.

3. The third method of estimating the indigo-blue is performed in the following manner. Equal weights of the samples to be tested are treated with equal quantities of concentrated sulphuric acid in the manner above described, and the solutions are then diluted with water and introduced into graduated glass cylinders, water being added to each until they all exhibit exactly the same shade of colour. The richer the sample is in indigo-blue, the greater will be the quantity of water necessary for this purpose, the number of measures of water required in each case indicating the relative amount. The great objection to this method consists in the circumstance, that the different kinds of indigo do not give the same shade of blue when their solutions in sulphuric acid are diluted with water, some exhibiting a pure blue colour, others a blue with a greenish, or purplish tinge. It therefore becomes difficult to institute an exact comparison between them.

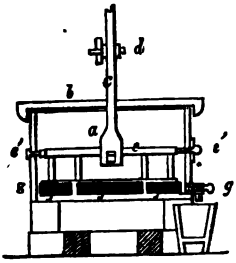
Employment of indigo in dyeing.— As indigo-blue is insoluble in water, and as it can penetrate the fibres of wool, cotton, silk, and flax only when in a state of solution, the dyer must study to bring it into this condition in the most complete and economical manner. This is effected either by exposing it to the concurrent action of alkalies and of bodies which have an affinity for oxygen superior to its own, such as certain metals and metallic oxides, or by mixing it with fermenting matters, or finally, by dissolving it in a strong acid, such as the sulphuric. The first method is that which is employed in the

Copperas or common blue vat. — Before being used the indigo must be broken into small pieces, the size of nuts, moistened with hot water, and then left for a day; after

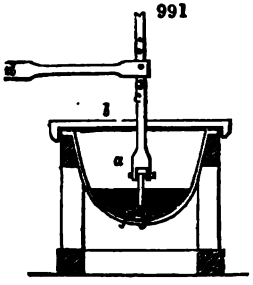
which it is reduced to a soft paste in a mill. The indigo mill is represented in *figs.* 990, and 991.

a, is a four-sided iron cistern, 2 feet 11 inches long, 19 inches broad, and 18 inches deep, cylindrical or rounded in the bottom, and resting upon gudgeons in a wooden frame. It has an iron lid *b*, consisting of two leaves, between which the rod *c* moves to and fro, receiving a vibratory motion from the crank *d*. By this construction, a frame *e*, which is made fast in the cistern by two points *e' e'*, is caused to vibrate, and

990



991



to impart its swing movement to six iron rollers *f, f, f,* four inches in diameter, three being on each side of the frame, which triturate the indigo mixed with water into a fine paste. This mill is capable of grinding 1 cwt. of indigo at a time. Whenever the paste is uniformly ground, it is drawn off by the stopcock *g*, which had been previously filled up by a screwed plug, in order to prevent any of the indigo from lodging in the orifice of the cock, and thereby escaping the action of the rollers.

Mills of other forms are also used occasionally. One of these consists of a hemispherical iron vessel open at the top, in which a stone of corresponding shape is fixed, so as to leave a small space between it and the sides and bottom of the vessel, in which the indigo undergoes the necessary trituration with water, the motion being produced by means of a vertical shaft fixed to the centre of the stone.

The other ingredients necessary for setting the vat are copperas or protosulphate of iron, newly slaked quicklime, and water. Various proportions of these ingredients are employed, as for instance, 1 part by weight of indigo (dry), 3 parts of copperas, and 4 of lime; or 1 of indigo, 2½ of copperas, and 3 of lime; or 8 of indigo, 14 of copperas, and 20 of lime; or 1 of indigo, ½ of copperas, and 1 of lime. The sulphate of iron should be as free as possible from the red oxide of iron, as well as from sulphate of copper, which would re-oxidise the reduced indigo-blue. The vat having been filled with water to near the top, the materials are introduced, and the whole after being well stirred several times is left to stand for about twelve hours. The chemical action which takes place is very simple. The protoxide of iron which is set at liberty by the lime reduces the indigo-blue, and the indigo-white is then dissolved by the excess of lime, forming a solution, which, on being examined in a glass, appears perfectly transparent and of a pure yellow colour, and becomes covered wherever it comes into contact with the air, with a copper-coloured pellicle of regenerated indigo-blue. The sediment at the bottom of the vat consists of sulphate of lime, peroxide of iron, and the insoluble impurities of the indigo, such as indigo-brown in combination with lime, as well as sand, clay, &c. If an excess of lime is present, a little reduced indigo-blue will also be found in the sediment in combination with lime.

The copperas vat is employed in dyeing cotton, linen, and silk. For cotton goods no other kind of vat is used at the present day. The dyeing process itself is very simple. The vat having been allowed to settle, the goods are plunged into the clear liquor, and after being gently moved about in it for some time are taken out, allowed to drain, and exposed to the action of the atmosphere. Whilst in the liquid the fabric attracts a portion of the reduced indigo-blue. On now removing it from the liquid it appears green, but soon becomes blue on exposure to the air in consequence of the oxidation of the reduced indigo-blue. On again plunging it into the vat, the deoxidising action of the latter does not again remove the indigo-blue which has been deposited within and around the vegetable or animal fibre, but on the contrary, a fresh portion of reduced indigo-blue is attracted, which on removal from the liquid is again oxidised like the first, and the colour thus becomes a shade darker. By repeating this process several times, the requisite depth of colour is attained. This effect cannot in any case be produced by one immersion in the vat, however strong it may be. The beauty of the colour is increased by finally passing the goods through

diluted sulphuric or muriatic acid, which removes the adhering lime and oxide of iron. After being used for some time the vat should be refreshed or fed with copperas and lime, upon which occasion the sediment must first be stirred up, and then allowed to settle again, so as to leave the liquor clear. The indigo-blue, however, is in course of time gradually removed, and by degrees the vat becomes capable of dyeing only pale shades of blue. When the colour produced by it is only very faint, it is no longer worth while using it, and the contents are then thrown away. In dyeing cotton with indigo, it seems to be essential that the reduced indigo-blue should be in combination with lime. If potash or soda be used in its stead it is impossible to obtain dark shades of blue.

When cotton piece goods are to be dyed of a uniform blue, they are not submitted to any preparatory process of bleaching or washing. Indeed the size contained in unbleached goods seems rather to facilitate than to impede the dyeing process. In dyeing these goods a peculiar roller apparatus is employed. When certain portions of the fabric are to retain their white colour a different plan is adopted. The pieces having been bleached, those portions which are to remain white are printed with so-called *resists*. These resists consist essentially of some salt of copper, mixed with an appropriate thickening material. The copper salt acts by oxidising the reduced indigo-blue at the surface, and thus rendering it insoluble before it can enter the interior of the vegetable fibre, since it is only when deposited within the fibre itself that the colouring matter becomes durably fixed. The pieces are now stretched upon square dipping frames, made of wood or of iron, furnished with sharp hooks or points of attachment. These frames are suspended by cords over a pulley, and thus immersed and lifted out alternately at proper intervals. In dyeing, a set of 10 vats is used, the first vat containing 5 or 6 lbs. of indigo, and the quantity increasing gradually up to 80 lbs. in the last vat. The pieces are dipped for 7½ minutes in the first vat, then taken out and exposed to the air for the same length of time, then dipped in the second vat, and so on to the last. After passing through the last vat, a small bit of the calico is dried, in order to see whether the colour is sufficiently dark. If it is not, the whole series must be dipped once more in the same vat in which the last dipping was performed. When the bottom of the vat is raked up so as to have more lime in suspension, the vat becomes what the dyer calls *hard*, that is to say, the oxide of copper of the resist is precipitated in a compact state, and consequently acts with more efficiency. But when the vat has been at rest for some time, and there is little lime in suspension, then it is called *soft*. When it is in this state, the oxide of copper is thrown down in a bulky form, and when the pieces are afterwards agitated in the liquor, in order to detach the oxide of iron, which always floats about in the vat, and attaches itself to the fabric, and which if left adhering would cause light stains, technically called *grounding*; then the oxide of copper is also detached, and the indigo penetrates to those parts which are to remain white. When cotton yarn is dyed in the copperas vat, the latter is generally heated by means of steam pipes passing through the liquor, the object being to give to the colour the peculiar gloss or lustre, which is required in this class of goods. No preparatory process is required, except simply steeping in hot water. In dyeing, wooden pins are put through the hanks, their ends resting on supports passing over the top of the vat, and the yarn is then slowly turned over, one half being in the liquor, the other half over the pins. It is then taken out, wrung, exposed to the air, and again dipped, this operation being repeated until the requisite shade is obtained.

The methods employed for producing the colours called *China blue* and *pencil blue* on calico have been described under Calico Printing.

The *urine vat* is prepared by digestion of the ground indigo in warmed stale urine, which first deoxidises the indigo-blue, and then dissolves it by means of its ammonia. Madder and alum are likewise added, the latter being of use to moderate the fermentation. This vat was employed more commonly formerly than at present, for the purpose of dyeing woollen and linen goods.

Woad vat.—In former times, woad was the only material known to the dyers of Europe for producing the blue colour of indigo. For this purpose it was previously submitted to a peculiar process of fermentation, and the product was named *pastel* in France. For most purposes indigo has taken the place of woad in the dye-house, and for cotton goods it is now used alone. In the dyeing of woollen goods, however, the use of woad has been retained to the present day, for the purpose rather of exciting fermentation and thus reducing the indigo which is employed at the same time, than of imparting any colour to the material to be dyed. Indeed, the woad used by woollen dyers in this country contains no trace of colouring matter. Various substitutes, such as rhubarb leaves, turnip tops, weld, and other vegetable matters, have accordingly been tried, but without success, since the fermentation is more steadily maintained by means of woad than by any other material. Pastel, which

does contain a little blue colouring matter, is preferred to woad by many of the French dyers. The materials employed in the ordinary woad or pastel vat, in addition to woad and indigo, are madder, bran, and lime. In the so-called *Indian* or *potash vat*, madder, bran, and carbonate of potash are used; in the *German vat*, bran, carbonate of soda, and quicklime, without woad. The chemical action which takes place in the woad vat is not difficult to understand. The nitrogenous matters of the woad begin, when the temperature is raised, to enter into a state of fermentation, which is kept up by means of the sugar, starch, extractive matter, &c., of the madder and bran. In consequence of the fermentation, the indigo-blue becomes reduced, and is then dissolved by the lime, thus rendering the liquid fit for dyeing. Great care is necessary in order to prevent the process of fermentation from passing into one of putrefaction, which if allowed to proceed would lead to the entire destruction of the indigo-blue in the liquor. If any tendency to do so is observed, it is arrested by the addition of lime, which combines with the acetic, lactic, and other organic acids that commence to form when putrefaction sets in. On the other hand, an excess of lime must also be avoided, since the reduced indigo-blue is thereby rendered insoluble, and unfit to combine with the material.

The following account of the method of dyeing woollen goods with indigo, as carried on at present in Yorkshire, may suffice to give a general idea of the process:—

The dye-vats employed are circular, having a diameter of 6 feet 6 inches, and a depth of 7 feet, and are made of cast iron ¼ of an inch in thickness. They are surrounded by brickwork, a space of 3 inches in width being left between the brickwork and the iron, for the purpose of admitting steam, by means of which the vats are heated. The interior surface of the brickwork is well cemented. In setting a vat the following materials are used:—5 cwt. of woad, 30 lbs. of indigo, 56 lbs. of bran, 7 lbs. of madder, and 10 quarts of lime. The woad supplied to the Yorkshire dyers is grown and prepared in Lincolnshire. It is in the form of a thick brownish-yellow paste, having a strong ammoniacal smell. The indigo is ground with water in the usual manner. The madder acts in promoting fermentation, but it also serves to give a reddish tinge to the colour. The lime is prepared by putting quicklime into a basket, then dipping it in water for an instant, lifting it out again, and then passing it through a sieve, by which means it is reduced to a fine powder, called by the dyers *ware*. The vat is first filled with water, which is heated to 140° Fahr., after which the materials are put in, and the whole is well stirred until the woad is dissolved or diffused, and it is then left to stand undisturbed over night. At 6 o'clock the next morning the liquor is again stirred up, and 5 quarts more lime are added. At 10 o'clock, 5 pints of lime are again thrown in, and at 12 o'clock the heat is raised to 120° Fahr., which temperature must be kept up until 3 o'clock, when another quart of lime is introduced. The vat is now ready for dyeing. When the process of fermentation is proceeding in a regular manner, the liquid, though muddy from insoluble vegetable matter in suspension, is of a yellow or olive-yellow colour; its surface is covered with a blue froth or a copper-coloured pellicle, and it exhales a peculiar ammoniacal odour; at the bottom of the vat there is a mass of undissolved matter, of a dirty yellow colour. If there is an excess of lime present, the liquor has a dark green colour, and is covered with a greyish film, and when agitated, the bubbles which are formed agglomerate on the surface, and are not easily broken. Cloth dyed in a liquor of this kind loses its colour on being washed. This state of the vat is remedied by the addition of bran, and is of no serious consequence. When, on the other hand, there is a deficiency of lime, or in other words, when the fermentation is too active, the liquor acquires first a drab, then a clay-like colour; when agitated, the bubbles which form on its surface burst easily, and when stirred up from the bottom with a rake it effervesces slightly, or *frets* as the dyers say. If the fermentation be not checked at this stage, putrefaction soon sets in, the liquid begins to exhale a fetid odour, and when stirred evolves large quantities of gas, which burn with a blue flame on the application of a light. The indigo is now totally destroyed, and the contents of the vat may be thrown away. No further addition of woad is required after the introduction of the quantity taken in first setting the vat, the fermentation being kept up by adding daily about 4 lbs. of bran, together with 1 quart or 3 pints of lime. Indigo is also added daily for about three or four months. The vat is then used for the purpose of dyeing light shades, until the indigo contained in it is quite exhausted, and its contents are then thrown away.

Woollen cloth before being dyed is boiled in water for one hour, then passed immediately into cold water. If it be suffered to lie in heaps immediately after being boiled, it undergoes some change, which renders it afterwards incapable of taking up colour in the vat. When a purple bloom is required on the cloth, it is dyed with cudbear to a light purple shade before being dipped. In dyeing, the cloth is placed on a network of rope attached to an iron ring, which is suspended by four iron chains at

a depth of about 3 feet beneath the surface of the liquor. The cloth is stirred about in the liquor by means of hooks for about 20 or 30 minutes. It is then taken out and well wrung. It now appears green, but on being unfolded and exposed to the air rapidly becomes blue. When the vat contains an excess of lime the cloth has a dark green colour when taken out. It is then passed through hot water and dipped again, if a darker shade is required. When woollen flocks are to be dyed, they are placed in a net made of cord, which is suspended by hooks at the side of the vat. They are then transferred to a stronger net and wrung out by several men. In dyeing flocks a more active fermentation of the vat is required than with cloth.

The process of dyeing by means of sulphate of indigo is quite different from indigo dyeing in the vat. This process was discovered by Barth, at Grossenhayn in Saxony, about the year 1740, and the colour produced by it is hence called *Saxon blue*. The method of purifying sulphate of indigo, by immersing wool in the solution of crude indigo in oil of vitriol, previously diluted with water, has been described above. The process of making sulphate of indigo or *extract of indigo*, as it is called, as now practised on the large scale, is as follows:—1 lb. of indigo is mixed with from 8 to 9 lbs. of oil of vitriol, and the mixture is left to stand for some hours in a room, the temperature of which is 90° Fahr. It is then diluted with water, and filtered through paper. There is left on the filter a dirty olive-coloured residue, which is used for some purposes by woollen dyers. By now adding common salt to the liquid, a blue precipitate of sulphate of indigo is produced, which is collected on a filter, and washed with a solution of salt in order to remove the excess of acid. No neutralisation with alkali is required when this plan is pursued. The blue produced on wool and silk by means of sulphate of indigo is very fugitive, and is now seldom required, its place having been in a great measure taken by the blue from prussiate of potash. The chief use of sulphate of indigo is for dyeing compound colours, such as green, olive, grey, &c.

INGRAIN. Wools, &c., are said to be dyed *ingrain* when they are subjected to that process before manufacture,

INK. (*Encre*, Fr., *Tinte*, Germ.)

Writing Ink may be and is prepared in many different ways; but it is essentially a tanno-gallate of iron.

Nutgalls, sulphate of iron, and gum are the only substances truly useful in the preparation of ordinary ink; the other things, often added, merely modify the shade and considerably diminish the cost to the manufacturer upon the great scale. Many of these inks contain little gallic acid or tannin, and are therefore of inferior quality. To make 12 gallons of ink we may take, 12 pounds of nutgalls, 5 pounds of green sulphate of iron, 5 pounds of gum Senegal, 12 gallons of water. The bruised nutgalls are to be put into a cylindrical copper, of a depth equal to its diameter, and boiled during three hours, with three-fourths of the above quantity of water, taking care to add fresh water to replace what is lost by evaporation. The decoction is to be emptied into a tub, allowed to settle, and the clear liquid being drawn off, the lees are to be drained. Some recommend the addition of a little bullock's blood, or white of egg, to remove a part of the tannin. But this abstraction tends to lessen the product, and will seldom be practised by the manufacturer intent upon a large return for his capital. The gum is to be dissolved in a small quantity of hot water, and the mucilage thus formed, being filtered, is added to the clear decoction. The sulphate of iron must likewise be separately dissolved, and well mixed with the above. The colour darkens by degrees, in consequence of the peroxidisement of the iron, on exposing the ink to the action of the air. But ink affords a more durable writing when used in the pale state, because its particles are then finer and penetrate the paper more intimately. When ink consists chiefly of tannate of peroxide of iron, however black, it is merely superficial, and is easily erased or effaced. Therefore, whenever the liquid made by the above recipe has acquired a moderately deep tint, it should be drawn off clear into bottles and well corked up. Some ink makers allow it to mould a little in the casks before bottling, and suppose that it will thereby be not so liable to become mouldy in the bottles.

From the comparatively high price of gallnuts; sumach, logwood, and even oak bark are too frequently substituted, to a considerable degree, in the manufacture of ink; but always injuriously.

The ink made by the recipe given above, is much more rich and powerful than many of the inks commonly sold. To bring to their standard a half more water may safely be added, or even twenty gallons of tolerable ink may be made from that weight of materials, as I have ascertained.

Sumach and logwood admit of only about one half of the copperas that galls will take to bring out the maximum amount of black dye.

Lewis, who made exact experiments on inks, assigned the proportion of three parts of galls to one of sulphate of iron, which, with average galls, will answer very well; but good galls will admit of more copperas.

Red ink.—This ink may be made by infusing for three or four days in weak vinegar, Brazil wood chipped into small pieces; the infusion may then be boiled upon the wood for an hour, strained and thickened slightly with gum Arabic and sugar. A little alum improves the colour. A decoction of cochineal with a little water of ammonia, forms a more beautiful red ink, but it is fugitive. An extemporaneous red ink of the same kind may be made by dissolving carmine in weak water of ammonia, and adding a little mucilage.

Blue ink. — Mr. Stephens's patent blue ink is made by dissolving Prussian blue in a solution of oxalic acid. The blue should be washed in dilute muriatic acid. M. Harnung has given the following as the best formula for blue ink: —

Mix 4 parts of perchloride of iron in solution with 750 parts of water, then add 4 parts of cyanide of potassium dissolved in a little water; collect the precipitate formed, wash it with several additions of water, allow it to drain until it weighs about 200 parts; add to this one part of oxalic acid, and promote solution of the cyanide by shaking the bottle containing the mixture. The addition of gum and sugar is useless, and even appears to exercise a prejudicial effect on the beauty of the ink. It may be kept without any addition for a long time.

China or *Indian ink.* — Proust says, that lamp black purified by potash lye, when mixed with a solution of glue and dried, formed an ink which was preferred by artists to that of China. M. Merimée, in his interesting treatise entitled *De la Peinture à l'Huile*, says, that the Chinese do not use glue in the fabrication of their ink; but that they add vegetable juices, which render it more brilliant and more indelible upon paper. When the best lamp black is levigated with the purest gelatine or solution of glue, it forms no doubt an ink of a good colour, but wants the shining fracture, and is not so permanent on paper as good China ink, and it stiffens in cold weather into a tremulous jelly. Glue may be deprived of the gelatinising property by boiling it for a long time, or subjecting it to a high heat in a Papin's digester; but as ammonia is apt to be generated in this way, M. Merimée recommends starch gum made by sulphuric acid to be used in preference to glue. He gives, however, the following directions for preparing this ink with glue. Into a solution of glue he pours a concentrated solution of gall-nuts, which occasions an elastic resinous-looking precipitate. He washes this matter with hot water, and dissolves it in a spare solution of clarified glue. He filters anew, and concentrates it to the proper degree for being incoporated with the purified lamp black. The astringent principle in vegetables does not precipitate gelatine when its acid is saturated, as is done by boiling the nut-galls with limewater or magnesia. The first mode of making the ink is to be preferred. The lamp black is said to be made in China, by collecting the smoke of the oil of sesame. A little camphor (about two per cent.) has been detected in the ink of China, and is supposed to improve it. Infusion of galls renders the ink permanent on paper.

Indelible ink. — A very good ink, capable of resisting chlorine, oxalic acid, and ablution with a hair pencil or sponge, may be made by mixing some of the ink made by the preceding prescription, with a little genuine China ink. It writes well. Many other formulæ have been given for indelible inks, but they are all inferior in simplicity and usefulness to the one now prescribed. Solution of nitrate of silver thickened with gum, and written with upon linen or cotton cloth, previously imbued with a solution of soda, and dried, is the ordinary permanent ink of the shops. Before the cloths are washed the writing should be exposed to the sunbeam, or to bright daylight, which blackens and fixes the oxide of silver. It is easily discharged by chlorine and ammonia.

A good permanent ink may be made by mixing a strong solution of chloride of platinum, with a little potash, sugar, and gum to thicken. The writing made therewith should be passed over with a hot smoothing iron to fix it.

Another indelible ink may be prepared by adding lamp black and indigo to a solution of the gluten of wheat in acetic acid. This ink is of a beautiful black colour, at the same time cheap, and cannot be removed by water, chlorine, or dilute acids. M. Herberger gives the following directions for its preparation: — Wheat gluten is carefully freed from the starch, and then dissolved in a little weak acetic acid; the liquid is now mixed with so much rain water that the solution has about the strength of wine vinegar, that is, neutralises $\frac{1}{10}$th of its weight of carbonate of soda. 10 grains of the best lamp black and 2 grains of indigo, are mixed with 4 ounces of the solution of gluten, and a little oil of cloves added. This ink may be employed for marking linen, as it does not resist mechanical force.

Indelible ink of Dr. Traill is essentially the same as the above.

French indelible ink is made of Indian ink diffused through dilute muriatic acid for writing with quills, and through weak potash lye for writing with steel pens.

Ink, Printing. — This is essentially a combination of lamp black, — finely divided carbon, — with oil. Mr. Underwood, in a communication made by him to the Society of Arts, well defines the necessary qualifications of a good ink.

1st. It must distribute freely and easily, and work sharp and clean.

2nd. It must not have too much tenacity for the type, but have a much greater affinity for the paper, and so come off freely upon it.

3rd. It must dry almost immediately on the paper, but not dry at all on the type or rollers; this is a great desideratum, especially for newspapers.

4th. It should be literally proof against the effects of time and chemical reagents, and never change colour.

Great attention must be paid to the quality of the linseed oil employed, and even the character of seed from which the oil is obtained should not be neglected.

The linseed oil is clarified from the fatty matters, and the pure oil is boiled with great care at a carefully regulated temperature; and during the boiling, the best pale yellow soap is added to give it consistency, and the required dryers are also now mixed with it. The best black is that obtained from the smoke of naphtha, the combustion being carefully regulated. This black is ground up carefully with the drying oil, which has assumed somewhat of the character of a varnish, and the ink is complete.

Gold and silver inks are prepared by grinding upon a porphyry slab with a muller gold or silver leaves, with white honey, until they are reduced to the finest possible state of division. The honey is thoroughly washed from the powdered metals, and these are mixed up with gum water.

INKING ROLLER. See PRINTING.

IODINE (*Iod*, Fr.; *Iod*, Germ.) is one of the elementary substances; it was accidentally discovered in 1812 by M. Courtois, a manufacturer of saltpetre at Paris. He found, that in the manufacture of soda from the ashes of seaweeds, the metallic vessels, in which the processes were conducted, became much corroded; and in searching for the cause of the corrosion, he discovered this now important substance. It was first described by Clement in 1813, but was afterwards more fully investigated by Davy and Gay-Lussac.

Gay-Lussac and Clement at first looked upon hydriodic acid as hydrochloric acid, until Sir H. Davy suggested the idea of its being a new and peculiar acid, and iodine as a substance analogous in its chemical relations to chlorine.

It was named iodine from the Greek word ἰώδης, violet-coloured, on account of the colour of its vapour.

Iodine exists in many mineral waters in combination with potassium and sodium.

In the mineral kingdom, iodine has been found in one or two rare ores, as in a mineral brought from Mexico, in which it existed in combination with silver, and also in one from Silesia in combination with zinc.

It exists also in very small quantities in sea water, from which it is extracted by many sea-weeds, which act therefore as concentrators of iodine; these sea-weeds when dried and ignited yield an ash, technically called kelp, from which all the soda of commerce was previously obtained, but the chief value of the kelp now is on account of the iodine which it yields. The following is the process most generally adopted for the extraction of the iodine from the sea-weeds.

The sun-dried sea-weed is incinerated in shallow excavations at a *low* temperature, for if the temperature was allowed to rise too high a considerable quantity of iodide of sodium would be lost by volatilisation. The half-fused ash or kelp which remains is broken into fragments, and treated with boiling water, which dissolves about one half of the ash.

The liquid thus obtained is evaporated, when on cooling the more crystallisable salts separate, viz. sulphate and carbonate of soda, with some chloride of potassium. The mother liquor still contains the iodide of sodium, sulphide of sodium, sulphide and some carbonate of soda. This liquor is then mixed with about one-eighth of its bulk of sulphuric acid, and allowed to stand for twenty-four hours; carbonic and sulphurous acid, and sulphuretted hydrogen gases escape, a fresh quantity of sulphate of soda crystallising out, mixed with a precipitate of sulphur.

The supernatant acid liquor is then transferred to a leaden still, to which is adapted a double tubulated leaden head luted on with pipe-clay; it is then heated to 140° F., when binoxide of manganese is added.

The temperature may be gently raised to 212° F., but not higher, as some chlorine would come over, and combine with some of the iodine, forming chloride of iodine.

The iodine is condensed in spherical glass condensers, each having two mouths

opposite to each other, and inserted the one into the other, the end one being fitted to the neck of the leaden head.

The iodine is purified by resublimation.

The following formula represents the reaction:

Iodide of Sodium.	Oxide of Manganese.	Sulphuric Acid.	Sulphate of Soda.	Sulphate of Manganese.	Iodine.	Water.
NaI +	MnO^2 +	$2HSO^4$ =	$NaSO^4$ +	$MnSO^4$ +	I +	$2HO$

The British iodine is exclusively manufactured at Glasgow, from the kelp of the west coast of Ireland, and the western islands of Scotland.

Iodine is a crystallisable solid, its primary form being a rhombic octohedron. It is however usually met with in micaceous, soft, friable scales, having a greyish-black colour, a metallic lustre, and an acrid hot taste. Even at ordinary temperatures, and more especially when moist, it is sensibly volatile, emitting an odour like that of chlorine, only much weaker.

At 225° F. it fuses, and at 347° F. boils, and is converted into a magnificent violet vapour. It may nevertheless be distilled, in the presence of steam, at a temperature of 212°, as is seen in the process of manufacture.

Iodine, in the solid state, has a specific gravity of 4·947, the specific gravity of the vapour being, according to Dumas, 8·716. Iodine is only very slightly soluble in water, it requiring 7000 parts of water to dissolve it; even then it imparts a yellow colour to the solution, and is used in that state as a test for starch, with which it forms a beautiful blue compound, which is, however, destroyed by heat.

Alcohol and ether dissolve it more readily; but the most powerful solvents of iodine are the solutions of the iodides. Iodine stains the skin, and most organic substances, of a brown colour; it attacks the metals rapidly; iron or zinc being readily dissolved by it if placed in water with it, an iodide of the metal being formed.

All the compounds of iodine with the metals and with hydrogen are decomposed by chlorine, and even by bromine, iodine being set free. Advantage is taken of this fact in detecting the presence of iodine. If the iodine exists in combination with a metal, or as hydriodic acid, its solution will not form the characteristic intense blue compound with starch, but on the addition of a little chlorine, or solution of bleaching powder, the iodine is set free and forms the blue compound with the starch. If however the iodine exists as iodic acid, it will not act upon starch until reduced by some reducing agent, as sulphurous acid. In using the chlorine care must be taken not to use too much, as it would unite with the iodine and prevent it acting on the starch.

Iodine is used to a considerable extent in medicine; when taken in large doses it is an irritant poison, but in small doses it is a most valuable medicine, particularly in glandular swellings, and in certain forms of goître. It is also much used in photography. The chemical symbol for iodine is I; its equivalent number 126·88; and the combining volume of its vapour 2. — H. K. B.

IRIDIUM. A rare white metal, found in connection with platinum and osmium. The natural combination of iridium and osmium is called the "native alloy," and on account of its hardness is used to point metallic pens. See NATIVE ALLOY.

IRISH MOSS. See ALGÆ.

IRON (*Fer*, Fr.; *Eisen*, Germ.) is a metal of a bluish-grey colour, and a dull fibrous fracture, but it is capable of acquiring a brilliant surface by polishing. Its specific gravity is 7·78. It is the most tenacious of metals, and the hardest of all those which are malleable and ductile. It is singularly susceptible of the magnetic virtue, but in its pure state soon loses it. When rubbed it has a slight smell, and it imparts to the tongue a peculiar astringent taste, called chalybeate. In a moist atmosphere iron speedily oxidises, and becomes covered with a brown coating called rust.

Every person knows the manifold uses of this truly precious metal; it is capable of being cast in moulds of any form; of being drawn out into wires of any desired strength or fineness; of being extended into plates or sheets; of being bent in every direction; of being sharpened, hardened, and softened at pleasure. Iron accommodates itself to all our wants, our desires, and even our caprices; it is equally serviceable to the arts, the sciences, to agriculture, and war; the same ore furnishes the sword, the ploughshare, the scythe, the pruning hook, the needle, the graver, the spring of a watch or of a carriage, the chisel, the chain, the anchor, the compass, the cannon, and the bomb. It is a medicine of much virtue, and the only metal friendly to the human frame.

The ores of iron are scattered over the crust of the globe with a beneficent profusion proportioned to the utility of the metal; they are found under every latitude, and every zone; in every mineral formation, and are disseminated in every soil. Considered in a purely mineralogical point of view, without reference to their importance for reduction, they may be reckoned to be 19 in number; namely, 1, native iron of three

kinds: pure, nickeliferous, and steelly; 2, arsenical iron; 3, yellow sulphuret of iron; 4, white sulphuret of iron; 5, magnetic sulphuret of iron; 6, black oxide of iron, either the loadstone, or susceptible of magnetism, and titaniferous; 7, compact *fer oligiste*, specular iron ore, as of Elba, and scaly *fer oligiste*; 8, hematite, affording a red powder; 9, hematite or hydrate of iron, affording a yellow powder, of which there are several varieties; 10, pitchy iron ore; 11, siliceo-calcareous iron, or yenite; 12, sparry carbonate of iron, and the compact clay iron-stone of the coal formation; 13, phosphate of iron; 14, sulphate of iron, native copperas; 15, chromate of iron; 16, arseniate of iron; 17, muriate of iron; 18, oxalate of iron; 19, titanate of iron.

Among all these different species, ten are worked by the miner, either for the sake of the iron which they contain; for use in their native state; or for extracting some principles from them advantageous to the arts and manufactures; such are arsenical iron, sulphate of iron, sulphuret of iron, and chromate of iron.

Native Iron.

A. *Telluric iron, nearly pure.*—This species, which is very rare, occurs in small grains and plates, or massive and disseminated. It is malleable and ductile, more so than ordinary malleable iron, and ranges in specific gravity between 7 and 7·8. It contains carbon, and occasionally some other metal, but *not nickel*. A specimen from Gross Camsdorf, in Thuringia, analysed by Klaproth, yielded 92·5 iron, 6 lead, and 1·5 copper: its structure was foliated and its texture crystalline. Native iron was found by Schreiber, in a vein at Oule, near Allemont in Dauphiné. A specimen containing 91·8 iron and 7·0 carbon (*Shepard*), was observed at Canaan in Connecticut, in a vein two inches broad lying in mica slate; another specimen was found in sandstone at Penn Yan, in New York. *John* states that it is mixed with the platina grains from South America, and more recently M. Molnar has affirmed that he has found native iron in the gold sands at Oláhpian. It is also stated that native iron, with 6 per cent. of silica, and a little sulphur, has been found with galena in the veins at Leadhills, and Mossier has found volcanic iron in lava at Graveneire in Auvergne. It had a steel grey or silver white colour, foliated texture, and hackly fracture. These instances would seem to prove the actual existence of native iron, which was for a long time disputed.

B. *Native nickeliferous or meteoric iron.*—This species is distinguished from the last by containing *nickel* and sometimes *cobalt*. It is very malleable, often cellular, but sometimes compact, and in parallel plates which pass into rhomboids or octahedrons. When polished and etched with acids, it exhibits linear and angular markings, or *Widmannstatt's* figures, as they have been termed, and from which an impression may be printed on paper. A very great number of undoubted meteorites have been described and analysed. The following table from Nicol's *Manual of Mineralogy* exhibits the composition of some of the most remarkable.

	Iron.	Nickel.	Cobalt.	Copper.	Manganese.	Magnesium.	Sulphur.	Chlorine.	Insol. Matter.	Total.
1	93·78	3·81	0·21	- -	- -	- -	- -	- -	2·20	100
2	88·04	10·73	0·46	0·07*	0·13	0·05	trace	- -	0·48	100
3	88·23	8·52	0·76	- -	trace	0·28	trace	- -	2·21	100
4	89·78	8·89	0·67	- -	- -	- -	- -	- -	- -	99·34
5	85·61	12·27	0·89	- -	- -	- -	- -	- -	- -	98·77
6	90·88	8·45	0·67	0·002	- -	- -	- -	- -	- -	100
7	66·56	24·71	- -	- -	3·24†	- -	4·00	1·48	- -	99·99
8	90·24	9 76	- -	- -	- -	- -	- -	- -	- -	100
9	83·57	12·67	- -	- -	- -	- -	- -	0·91‡	- -	99·54
10	92·58	5·71	- -	trace§	- -	- -	- -	- -	1·40	99·69
11	81·8	11·9	1·0	- -	0 2	- -	5·1	- -	- -	100

* With tin+0·04 carbon. † With chromium. ‡ +2·30 sulphuret of iron. § With arsenic.

The insoluble matter in the above contains in 100 parts—

In No.	Iron.	Nickel.	Phosphorus.	Silica.	Carbon.	Magnesium.	Total.
1	65·99	15·01	14·02	2·04	1·42	- -	98·4
2	48·67	18·33	18·47	- -	- -	9·66	95·13
3	68·11	17·72	14·17	- -	- -	- -	100·0
10	44·1	24·50	11·4	? 10·0	- -	- -	90 0

The above analyses are of:—1. A mass of 103 lbs. weight, which fell at Bohumilitz, in Bohemia, in 1829. 2. A mass weighing 1,600 lbs., found in 1748, near Krasnojarsk, on the Yenisei. 3. The so-called "Verwünschte Burggraf," from Elbogon in Bohemia, which weighed 191 lbs. 4. A mass of 71 Vienna pounds weight, which fell at Hraschina, near Agram, in Croatia, on 26th May, 1751. 5. A mass in the Haerlaem Museum, found in 1793, on the plain between the Great Fish River and Graf Reynet, in the Cape Colony, originally weighing 300 lbs. 6. Found at Lénarto, in Hungary, original weight 194 lbs. 7. From Clairborne in Alabama. 8. From Potosi. 9. Is a more recent analysis of the same. 10. From Lockport in North America. 11. From Bitburg, near Treves, which weighed above 3,300 lbs.

According to *Shepard* (Silliman's American Journal), the fall of meteoric stones is confined principally to two zones. The one belonging to America lies between 33° and 44° N. lat., and is about 25° in length. Its direction is more or less from N. E. to S. W., following the general line of the Atlantic coast. Of all the occurrences of this phenomenon during the last 50 years, 92·8 per cent. have taken place within these limits, and mostly in the neighbourhood of the sea. The zone of the eastern continent, with the exception that it extends 10° further to the north, is bounded by the same degrees of latitude, and follows a similar north-east direction; but it has more than twice the length of the American zone. Of the observed falls of aërolites, 90·9 per cent. occurred within this area, and were also concentrated in that half of the zone which extends along the Atlantic.

The most remarkable masses of meteoric iron are, that found by Don Rubin de Celis, in Tucuman in South America in 1783, weighing 300 cwts.; that discovered in 1784 on the Riacho de Bendego in Brazil, estimated to measure 32 cubic feet, and to weigh 17,300 lbs.; and that on the Red River in Louisiana, weighing above 3000 lbs., and presenting distinct octahedral crystals.

c. 1. *Native Steel-Iron.*—This substance has all the characters of cast steel; it occurs in a kind of small button ingot, with a finely striated surface and a fracture exceedingly fine grained. It is hardly to be touched by the file, and will scarcely flatten under the hammer. M. Mossier found this native steel at the village of Bouiche, near Nery, department of the Allier, in a spot where there had existed a seam of burning coal. A mass of 16 lbs. 6 oz. of native steel was discovered in that place, besides a great many small globules.

2. *Mispickel; Diprismatic Arsenical iron; Arsenikkies.* This mineral is found massive, granular, or columnar, and disseminated. It is brittle, with an uneven fracture; colour, silver white, or almost steel grey, with a greyish or yellowish tarnish; specific gravity 6—6·2. When heated in a closed tube it yields first a red, then a brown sublimate of sulphuret of arsenic, and then metallic arsenic. Some varieties contain silver or gold, in others part of the iron is replaced by cobalt. Viewing it as a double sulphide and arsenide of iron, its formula would be $FeS^2 + FeAs$, which requires iron, 33·5; sulphur, 19·9; arsenic, 46·6. A specimen analysed by Plattner gave, iron, 34·46; sulphur, 20·07; arsenic, 45·46. Mispickel is common in the mines of Freiberg in Saxony, and in the tin mines of Bohemia, Silesia, and in Cornwall. It is of no use as an ore of iron, but it is occasionally worked for the silver it contains, and as an ore of arsenic.

3. *Yellow sulphuret of iron; Prismatic iron pyrites; or Marcasite.*—The bronze or brass yellow colour enables us to recognise this mineral. At the blowpipe it gives off its sulphur, and is converted into a globule attractable by the magnet. It is brittle, with a conchoidal or uneven fracture. Sp. gr. 4·9—5·1. It is soluble in nitric acid with deposition of sulphur, but is scarcely affected by hydrochloric acid. It is a bisulphide of iron (FeS^2), 46·7 iron, 53·3 sulphur. Hatchett found 47·3 iron, 52·7 sulphur; and Berzelius, 46·08 iron, and 53·92 sulphur. It is very liable to decomposition, being sometimes oxidised into sulphate of iron, and sometimes into hydrated peroxide, the sulphur becoming altogether eliminated. It is one of the most common minerals in rocks of all ages and classes; it occasionally contains both gold and silver. It is used for the manufacture of sulphur, sulphuric acid, and alum, but as an ore of iron it has no commercial value.

4. *Hexahedral iron pyrites* or *pyrene.*—This mineral is distinguishable from the former only by its colour and form of crystallisation, and was hence till lately confounded with it by mineralogists. Its surface is often radiated.

5. *Magnetic iron pyrites, pyrrhotine, the magnetkies of the Germans.*—This mineral occurs chiefly in the igneous and crystalline, or older stratified rocks, in veins with various ores. Its colour is between bronze yellow and copper red, with a pinchbeck-brown tarnish, streak greyish-black, and more or less magnetised. When heated in an open tube it yields sulphurous fumes, but no sublimation; before the blowpipe on charcoal in the reducing flame it fuses to a black strongly magnetic globule; it is

soluble in hydrochloric acid, evolving sulphuretted hydrogen and depositing sulphur. According to G. Rose, this mineral always contains a larger quantity of sulphur than corresponds with the simple sulphide FeS; and he adopts for it the formula $5FeS + Fe^2S^3$; corresponding with 60·44 iron, and 39·56 sulphur, which agrees very closely with the analyses that have been made by Stromeyer, H. Rose, and others.

6. *Black oxide of iron; Magnetite*, or *native loadstone*, or *octahedral iron ore.* —This very rich and valuable ore occurs especially in igneous or metamorphic rocks, either in distinct crystals, or, as in many basalts, disseminated through the mass, when it frequently imparts magnetic properties to the rocks, especially to greenstone, serpentine or basalt. It also forms beds in gneiss, in chlorite, mica, hornblende, and clayslates, in marble, greenstone, and other rocks, but seldom appears in veins. The largest known masses occur in the northern parts of the globe, in Scandinavia, Lapland, Siberia, and North America. Less extensive masses occur in the Harz, in Saxony, Bohemia, Silesia, and Styria; and in Southern Europe, in Elba and Spain. *Magnetite* is the most important ore of iron in Norway, Sweden, and Russia. The Dannemora mines in Sweden, wrought in an open quarry 150 feet broad, and 500 feet deep, furnish the fine Oeregrund iron, largely imported into England for the manufacture of steel. Some highly magnetic varieties, especially from Siberia and the Harz, form natural magnets, possessing distinct polarity. Others become polar only after contact with magnets of sufficient power. Magnetic iron ore fuses with extreme difficulty: it is not acted upon by nitric acid, but when powdered is soluble in hydrochloric; its specific gravity varies from 4·24 to 5·4. The chemical formula of pure magnetite is FeO,Fe^2O^3, corresponding to 31·03 of protoxide, and 68·77 of peroxide of iron, or of 72·40 iron, and 27·60 oxygen, which agrees closely with the analyses of Berzelius, Kobell, and Karsten.

Two specimens of magnetic iron ore from Cornwall had the following compositions (*Dr. Noad*):—

Water	2·50	3·20
Protoxide of iron	20·00	13·00
Peroxide of iron	44·40	66·50
Oxide of manganese	·16	·56
Alumina	5·20	3·60
Lime	0·60	0·56
Magnesia	1·00	1·52
Sulphuric acid	0·04	0·04
Phosphoric acid	0·50	0·57
Insoluble residue	24·20	9·40
	99·60	98·95

7. *Hæmatite; Specular iron; Fer oligiste; Rhombohedral iron ore.* — This ore has a metallic lustre; colour, iron black to steel grey, but often tarnished; the light transmitted through the thin edges of its crystals appears of a beautiful red colour. Its powder is always of a well marked brown red hue, passing into cherry red, which distinguishes it from the black oxide ore; its fracture is conchoidal or uneven; it is brittle, and its specific gravity is 5·2. Its chemical composition is Fe^2O^3, 70·03 iron, and 29·97 oxygen, but it sometimes contains oxide of *titanium*, or titanic acid, *chrome*, or *silica*; in the reducing flame of the blowpipe, it becomes black and magnetic.

Hæmatite is one of the most abundant ores of iron. The specular variety occurs chiefly in the older crystalline rocks in large beds or veins. The mines of the island of Elba celebrated from antiquity, still furnish the finest crystals, which occur in druses of the massive variety along with pyrites and quartz: fine crystals are likewise produced from St. Gotthardt, Framont, in the Vosges mountains, the Harz, Altenberg in Sweden, and from Katherinenburg in the Ural. Beautiful specimens of the micaceous variety occur at Zorge and other parts of the Harz, at Tincroft in Cornwall, Tavistock in Devonshire, in Wales, Cumberland, and Perthshire. It also occurs in volcanic rocks, as in Auvergne, on Vesuvius, Ætna, and the Lipari islands, especially Stromboli, where some fine crystals, three inches broad and four long, have been procured.

8. *Red hæmatites.* — These ores are found in the greatest abundance in the mountain or carboniferous limestone formations. The most abundant deposits in this country are those of Lancashire, Cumberland, and the Forest of Dean, where the ore exists in almost unlimited quantity. In the latter locality they were worked most extensively at a very early date, and though as a class they are not rich, yet from the great masses in which the ore is found, its cost of production is very low, about 2*s.* to 3*s.* per ton (*Blackwell*). The iron made from the Forest of Dean ore, is of

the quality called *red-short*, and is especially celebrated for the manufacture of tin plates. This ore is raised extensively for shipment to the iron works of South Wales.

The varying quality of the Forest of Dean ores is shown in the following analyses. (*Dr. Noad.*)

	I.	II.	III.	IV.	V.
Water	3·16	5·80	2·90	2·11	7·70
Carb. lime	27·00	25·50	39·60	14·10	18·40
Carb. magnesia	15·00	18·30	25·00	17·10	18·80
Oxide manganese	- -	- -	- -	- -	·20
Peroxide of iron	40·80	38·10	29·00	59·70	36·62
Alumina	6·00	3·60	- -	1·89	- -
Sulphuric acid	traces	traces	traces	traces	traces
Phosphoric acid	traces	traces	traces	0·20	0·30
Insoluble residue	8·84	8·70	3·50	5 10	18·00
	100·80	100·00	100·00	100·26	100·02

The hæmatite of Whitehaven occurs in the carboniferous limestone near the outcrop or surface edge of the slaty rocks upon which that formation rests. The greater part of the excavations from which it is extracted are subterraneous, and so extensive is often the mass of iron ore in which the workings are carried on, that it is difficult in such situations to obtain a clear idea of the nature of this important deposit. (*Warrington Smyth.*) 67,248 tons of the hæmatite of the Whitehaven district is smelted on the spot, at the Cleator Moor and Workington works, and 264,296 tons are sent into the iron making districts. In the year 1858, 436,595 tons were sent away by sea and railway from the Ulverstone district, and no less than 690,840 tons of hæmatite were exported during 1858 (*Hunt*), for the supply of Staffordshire, South Wales, and other districts from these two localities. Considering its quality, it brings but a low price, viz. from 11*s.* 6*d.* to 13*s.* 6*d.* per ton.

The following analyses of some carefully selected samples of the hæmatite of the carboniferous limestone are by Messrs. Dick and Spiller. (*Memoirs of the Geological Survey of Great Britain. The Iron Ores of Great Britain.* Part I.)

	Cleaton Moor.	Cleaton Moor.	Ulverstone.	Lindall Moor, near Ulverstone.
Peroxide of iron	95·16	90·36	86·50	94·23
Protoxide of manganese	0·24	0·10	0·21	0·23
Alumina	- -	0·37	- -	0·51
Lime	0·07	0·71	2·77	0·05
Magnesia	- -	0·06	1·46	trace
Phosphoric acid	trace	trace	trace	trace
Sulphuric acid	trace	trace	0·11	0·09
Bisulphide of iron	trace	0·06	- -	0·03
Water, hygroscopic	- -	- -	- -	0·39
„ combined	- -	- -	- -	0·17
Insoluble residue	5·68	8·54	6·55	5·18
Carbonic acid	- -	- -	2·96	- -
	101·15	100·20	100·56	100·88

The carboniferous limestones of Derbyshire and Somersetshire also contain veins and deposits of hæmatite, though of a quality not equal to those of Lancashire; the same ore is also met with in the Devonian series of Devon, West Somerset, and Cornwall.

9. *Brown Hæmatites; Brown oxide of iron; Hydrous oxide of iron.*—This species affords always a yellow powder, without any shade of red, which passes sometimes into the bistre brown, or velvet black. At the blowpipe it becomes brown, and very attractable by the magnet; but after calcination and cooling the ore yields a red

powder, which stains paper nearly as red as the hæmatite does, and which is much employed in polishing metals. All the yellow or brown oxides contain a large proportion of water in chemical combination. There are several varieties, which assume globular, reniform, stalactitic, and fruticose shapes. In many countries this is one of the most plentiful and valuable ores of iron; in the oolitic form it supplies by far the greater number of the French iron works. In that state it is found in Normandy, Berry, Burgundy, Lorraine, and many other places. It is this ore which exclusively supplies the Belgian iron works. It is found in this country in considerable quantities at Alston Moor and Durham, but is only used to a limited extent, on account of its association with lead and zinc.

The iron which the brown hæmatites produce does not at present stand high; it possesses fluidity, but has a great tendency to *cold shortness*, and is most suitable for foundry purposes.—*Blackwell.*

The chemical composition of pure brown hæmatite is $2Fe^2O^3 + 3HO$; 85·6 peroxide of iron (= 60 iron) and 14·4 water. Yellow ochre (gelbeisenstein) is considered by Hausmann to be a distinct species; a specimen analysed by him contained 81·6 peroxide of iron, and 18·4 water, corresponding to the formula $Fe^2O^3 + 2HO$. Bog iron ore is also a hydrated oxide of iron; it occurs chiefly in bogs, meadows, and lakes, especially in the level districts of Northern Germany and Sweden. In Britain it is most abundant in the northern and western islands of Scotland. It is generally very impure, sometimes containing as much as 10 per cent. of phosphoric acid, which renders it all but useless for iron making purposes. The *ætites*, or eagle stones, are also a variety of this ore; on breaking the balls so named, they are observed to be composed of concentric coats, the outside ones being very hard, but the interior becoming progressively softer towards the centre, which is usually earthy, and of a bright yellow colour, sometimes, however, the centre is quite empty, or contains only a few drops of water. *Ætites* occur in abundance, often even in continuous beds, in secondary mountains, and in certain argillaceous strata; when smelted they yield a good iron.

Some of the brown hæmatites contain a large percentage of manganese. Their general composition is illustrated in the following analyses (*Dr. Noad*).

	I.	II.	III.	IV.
Water	12·85	12·80	12·40	13·20
Oxide of manganese	3·08	9·60	8·80	11·20
Lime	—	—	—	—
Magnesia	1·72	1·10	1·20	1·08
Alumina	1·20	·92	1·20	1·04
Peroxide of iron	68·57	68·45	67·77	66·98
Sulphuric acid	0·11	0·11	0·10	0·096
Phosphoric acid	1·01	1·02	1·12	1·054
Insoluble residue	12·00	9·50	8·80	11·200
	100·54	101·20	99·79	100·85

10. *Pitchy hydrate of iron; Petticite; Eisensinter.*—This mineral occurs in many old mines, especially those near Freiberg; and also at Schneeberg in Saxony, Pleiss in Silesia, and Bleistadt in Bohemia. It is probably a product of the decomposition of mispickel: its composition, according to the analysis by Stromeyer being $F^2O^3,AsO^5 + F^2O^3,SO^3 + 15HO = 35$ peroxide of iron, 26 arsenic acid, 9 sulphuric acid, and 30 water. According to *Freisleben*, it is first fluid, and gradually separates in a solid form. In external characters it agrees with *Diadochite*, which is $Fe^2O^3,2PO^5 + 4Fe^2O^3,SO^3 + 32HO$, according to Gmelin from Plattner's analysis, viz. peroxide of iron, 36·69; phosphoric acid, 14·81; sulphuric acid, 15·15; water, 30·35.

11. *Yenite or Liëvrite; Hisingerite or thraulite; Nontronite: Pinguite;* and *Chloropal*, are rather rare minerals, composed of peroxide of iron and silica: the former contains about 12 per cent of lime; the others are destitute of this earth, but contain from 10 to 20 per cent. of water; the amount of silica in these minerals ranges between 30 and 40 per cent.

12. *Carbonate of iron; Sparry iron; Spathose iron; Sphärosiderite: Spatheisenstein.*—This important species has been divided into two varieties; spathose iron *proper*, and the compact carbonate, the clay iron stone of the coal formation. Sparry iron appears to range through nearly the same series of formations as the anhydrous hæmatites: it occurs in beds and masses often of immense extent, especially in Styria

and Carinthia. In the Erzberg, near Eisenerz in Styria, it rests on gneiss, and is wrought in an open quarry. The Stahlberg and Momel, near Schmalkald, the vicinity of Liegen, and Musen in Westphalia, show similar extensive masses; whilst in Anhalt and the Harz it forms large veins in greywacke or Devonian limestone. Other very extensive deposits of this ore are found in the Pyrenees, and the Basque provinces of Spain, as near Bilboa; and at Pacho near Bogota in New Grenada. Most of these localities yield fine crystals; and these also occur in metallic veins at Joachimsthal in Bohemia, Freiberg in Saxony, Klausthal in the Harz, Beeralstone in Devonshire, Alston Moor in Cumberland, and in many of the mines of Cornwall, particularly the rare hexagonal prisms (*Nicol*). In England the crystalline carbonate of iron occurs in the Devonians of South Somersetshire and North Devon, and in the carboniferous limestones of Northumberland.

The specific gravity of sparry carbonate of iron varies from 3·00 to 3·67. Its primitive form is, like that of carbonate of lime, *an obtuse rhomboid*. Without changing this form, its crystals are susceptible of containing variable quantities of carbonate of lime, till it passes wholly into this mineral. When heated before the blowpipe it turns brown without melting, and becomes attractable by the magnet after being slightly heated in the flame of a candle. Even by a short exposure to the air after its extraction from the mine, it also assumes the same brown tint, but without acquiring the magnetic quality: after long exposure to the air it becomes wholly converted into hydrated hæmatite.

The variations in composition of this important mineral are shown in the following analyses.

	Steinheim, Hanau.	*Rancié*, Pyrenees.	*Eisen*, Liegen.	Ehrenfrieders-dorf.	*Henry*, Somerset-shire.	*Nead*, Somerset-shire.
Protoxide of iron -	63·75	53·50	43·59	36·81	37·33	52·56
Sesquioxide of iron -	- -	- -	- -	- -	8·52	
Protoxide of manganese	0·75	6·50	17·87	25·31	12·65	4·82
Magnesia - - -	0·25	0·70	0·08	- -	4·52	2·41
Lime - - -	traces	- -	0·24	- -	traces	1·25
Carbonic acid - -	34·00	39·20	38·22	38·35	35·80	38·68
	98·75	99·90	100·00	100·47	98·82	99·72

This ore, viewed as a metallurgic object, is one of the most interesting and valuable that is known; it affords *natural steel* with the greatest facility, and accommodates itself best to the Catalan smelting forge. It was owing in a great measure to the peculiar quality of the iron which it produces that the excellence long remarked in the cutlery of the Tyrol, Styria, and Carinthia was due. It was called by the older mineralogists, *steel ore*.

Coal measure iron stones. — The compact carbonate of iron has no relation externally with the sparry variety. It comprehends most of the clay ironstones, particularly those which occur in flattened spheroidal masses of various sizes among the coal measures. The colour of this ore is often a yellowish brown, reddish grey, or a dirty brick red. Its fracture is close grained, it is easily scratched, and gives a yellowish brown or grey powder. It adheres to the tongue, has an odour slightly argillaceous when breathed upon; blackens at the blowpipe without melting, and becomes attractable by the magnet after calcination. The ironstones of the coal formation admit of a natural division into two great classes, viz. the *argillaceous*, and the *blackband* or *carbonaceous*. The earthy or lithoid carbonates occur in some regions in the upper limestone shales, and they extend upwards through the coal measures proper towards their higher limits; they likewise occur in extensive beds in the Jurassic formation, particularly in North Yorkshire; near the upper limit of the lias, or base of the oolites proper; and again higher, as nodules and perhaps as beds, in the middle oolites, or Oxford clays. They are also found extensively as courses of nodules in the Wealden series, and as beds in the green sand. When these gray carbonates contain lime in abundance, and when clay is not largely present, they are sometimes changed by atmospheric influences into hydrated hæmatites; in Northamptonshire, for example, and widely in France. The only great coal fields in Great Britain in which these ores do not occur in sufficient abundance to form the basis of a large production of iron, are those of Northumberland and Durham, and of Lancashire. The great importance of the argillaceous and blackband ironstones of our coal-fields is clearly shown by the fact, that they supply at least *nine-tenths* of the entire iron produced

(*Blackwell*). They vary considerably in their percentage of iron, which is generally not more than 30 to 33 per cent., but occasionally ranges as high as 40 per cent. They are rarely used when they contain less than 25 per cent. The varying proportions of iron, silica, and alumina which they contain is shown in the subjoined analyses of the ore from different localities.

	Bertrier.		
	Bressac.	Aveyron.	St. Etienne.
	I.	II.	III.
Water			
Carbonic acid	35·50	28·90	38·4
Protoxide of iron	35·00	54·20	41·8
Protoxide of manganese	0·30	1·10	4·1
Lime	- -	0·30	0·2
Magnesia	1·60	0·90	0·3
Silica	26·50	12·80	12·3
Alumina	11·80	1·80	3·2
Peroxide of iron			
Sulphuric acid, Phosphoric acid } *not determined*	,,	,,	,,
	100·70	100·00	100·30

Scotch Varieties.	Dr. Colquhoun.			
	IV.	V.	VI.	VII.
Carbonic acid	32·53	30·76	35·17	33·10
Protoxide of iron	35·22	38·80	53·03	47·33
Protoxide of manganese	- -	0·07	- -	0·13
Lime	8·62	5·30	3·33	2·00
Magnesia	5·19	6·70	1·77	2·20
Silica	9·56	10·87	1·40	6·63
Alumina	5·34	6·20	0·68	4·30
Peroxide of iron	1·16	0·33	0·23	0·33
Carbon	2·13	1·87	3·03	1·70
Sulphur	0·62	0·16	0·02	0·22
	100·37	101·00	98·61	97·94

Welsh Varieties.	Dr. Noad.			
	Red Vein.	Red Vein Pin.	Soap Vein.	Black Pin.
	VIII.	IX.	X.	XI.
Silica	8·31	15·40	9·54	12·00
Alumina (insoluble)	3·13	5·00	4·46	4·00
Carbonate of iron	73·79	57·99	77·34	71·70
Oxide of manganese	·92	·64	·53	1·42
Carbonate of lime	2·95	3·45	- -	2·64
Carbonate of magnesia	3·80	8·58	·90	4·23
Alumina (soluble)	2·52	3·52	2·50	1·15
Phosphoric acid	·53	·75	·57	·48
Sulphuric acid	traces.	traces.	traces.	traces.
Bisulphide of iron	·17	·24	·19	traces.
Potash	·48	·45	·53	·49
Organic matter and water	2·36	2·34	2·24	1·64
	98·96	98·36	98·80	99·74
Metallic iron	35·62	28·00	37·3	34·6

Cleveland Ironstones.	Mr. Crowder.			
	Easton Nab (Main Seam.)		Hutton Low Cross.	
	XII.	XIII.	XIV.	XV.
Silica	11·95	7·65	16·55	15·65
Peroxide of iron	6·73	1·20	- -	1·80
Protoxide of iron	39·05	43·35	37·41	35·75
Alumina	13·83	9·88	9·86	4·95
Lime	2·52	0·58	3·08	7·39
Magnesia	2·72	5·35	trace.	2·98
Sulphur	trace.	0·09	trace.	trace.
Phosphoric acid	1·02	3·87	0·67	5·05
Carbonic acid	16·38	22·36	26·32	23·47
Water	5·80	5·07	6·11	4·89
	100 00	100·00	100·00	100·00

Blackband, from the neighbourhood of Pontypool, South Wales.	Dr. Noad.	
	XVI.	XVII.
Carbonaceous matter	15·00	13·42
Carbonate of iron	61·00	64·44
Carbonate of magnesia	10·90	13·54
Carbonate of lime	13·20	8·60
	100·10	100·00
Iron per cent.	29·6	31·1

The quality of the iron produced from the argillaceous ironstone is extremely good, provided the coals used for smelting are good. The ore is always used in a calcined state, by which it loses in weight about one-third or one-fourth, the loss consisting of carbonic acid and water. The production of iron in South Wales, South Staffordshire, Northumberland, and Durham, rests almost entirely on the great beds of this mineral. In Scotland the ore almost exclusively used is the *blackband* or *carbonaceous ironstone*, immense deposits of which occur likewise in the coalfield of North Staffordshire; this variety sometimes contains as much as 25 to 30 per cent. of carbonaceous matter, but is usually free from much earthy matter; it often contains phosphoric acid in quantity sufficient to communicate to the iron the quality of cold-shortness. The discovery of this class of ironstone in Scotland by Mr. Mushet in 1801, and the power of using it alone in the furnace by means of hot blast, constituted a new era in the manufacture of iron, and gave to Scotland, till then an iron making district of little importance, the pre-eminence over all others, for the production of soft fluid iron, best suited to ordinary foundry purposes.—*Blackwell.*

In France the clay carbonates of the coal measures are only found of sufficient value to work in three localities, — in the coalfields of the Gard, of the Aveyron, and to a very limited extent in the coalfield of the Loire, near St. Etienne.—*K. Blackwell.*

In America it is largely distributed over Pennsylvania, Maryland, Virginia, Ohio, Illinois, North Carolina, and Kentucky; but from the difficulties of working it in the blast furnace, it is not in general use.

13. *Phosphate of iron; Blue iron; Vivianite.* — The colour of this mineral varies from indigo-blue to blackish green; the earthy variety is white in the beds, but changes blue on exposure to the air; heated in a closed tube it yields much water, intumesces, and becomes spotted with grey and red; before the blowpipe on charcoal, it fuses to a grey, shining, metallic granule. Transparent indigo-coloured crystals of phosphate of iron, sometimes an inch in diameter and two inches long, occur with iron and copper pyrites in the tin and copper veins at St. Agnes in Cornwall. It was first found in the auriferous veins at Vörospatak in Liebenberg; the earthy varieties are very common in Cornwall, Styria, North America, Greenland, and New Zealand. A specimen from St. Agnes, Cornwall, gave Stromeyer—phosphoric acid, 31·18; protoxide of iron, 41·23; water, 27·48; and another from New Jersey yielded to Rammelsberg—phosphoric acid, 28·40; protoxide of iron, 33·91; peroxide of iron, 12·06. It is sometimes used as a pigment, but is of no use as a smelting ore.

14. *Sulphate of iron, native green vitriol.*—This is formed by the oxygenation of sulphuret of iron, and is unimportant in a metallurgic point of view.

15. *Chromate of iron; Octahedral chrome ore; Chromite.*—This mineral occurs in serpentine, or in crystalline limestone, near this rock. It was first discovered at Gassin, in the Var department in France, and is found in Saxony, Silesia, Bohemia, and Styria; also in Norway; and in large masses in the Ural, near Katherinenberg. It has been found also in great abundance in Unst and Fetlar, in the Zetlands; the mineral is opaque, with a semi-metallic lustre; colour, iron or brownish-black, streak yellowish to reddish brown. A specimen from Norway, analysed by Von Kobell, gave protoxide of iron, 25·66; sesquioxide of chromium, 54·08; alumina, 9·02; magnesia, 5·36; and silica, 4·83; another specimen, from Chester in Pennsylvania, yielded to Seybert protoxide of iron, 36·00; oxide of chromium, 39·61; alumina 13·0; and silica, 10·60. It is used in the preparation of various pigments. For the treatment and use of the ore, see CHROME.

16. *Arseniate of iron; Pharmakosiderite; Wurfelerz.*—This mineral, which is rather rare, occurs in great beauty associated with copper ores in Cornwall; it has an olive green colour, and is rather brittle. Its composition, according to the analysis of Berzelius, is, arsenic acid, 40·4; peroxide of iron, 28·1; protoxide of iron, 12·6; water, 18·9.

17. *Muriate of iron.*

18. *Oxalate of iron; Oxalite; Humboldtine.*—This mineral, which occurs in the form of capillary crystals in the brown coal at Kolosoruk, near Bilin, in Bohemia, and at Gross Almerode in Hessia, is composed, according to the analysis of Rammelsberg, of oxalic acid, 42·40; protoxide of iron, 41·13; and water, 16·47.

19. *Titanate of iron; Titanitic iron; Ilmenite.*—This variety occurs in various formations, as in the *miascite* of the Ilmen mountains; *in talc*, with dolomite, at Gastein in Salzburg; in the *zircon-syanite* at Egersund in Southern Norway; and in *gneiss*, with magnetic iron ore, at Tvedestrand, and Kragerse, near Arendal. It is extremely infusible, and is considered injurious when mixed with other ores. Its chemical composition, according to H. Rose and Scheerer, is a combination of peroxide of iron, and blue oxide of titanium, in various proportions, the specific gravity increasing with the amount of iron.

20. *Tungstate of iron; Wolfram,* — occurs with tin ore, forming fine crystals, at Altenberg in Saxony; at Schlackenwald in Bohemia; and in France, in quartz veins. In Cornwall, especially near Redruth, it is sometimes so abundant as to render the tin ore wholly valueless. An analysis of a specimen from Cumberland gave Berzelius, tungstic acid, 78·77; protoxide of iron, 18·32; protoxide of manganese, 6·22; and silica, 1·25.

There is abundance of evidence that iron was well known in the early ages, and was applied to various useful purposes. The earliest method of working the furnace where ores were smelted seems to have been by exposing them to the wind: the furnaces, perforated with holes, were built on eminences, and could only be worked when there was a strong breeze; the fire was regulated by opening and shutting the apertures. Mungo Park gives, in his "Travels in Africa," the following interesting account of an iron smelting operation in Kamalia, at which he himself assisted: "The ironstone was broken into pieces the size of a hen's egg; a bundle of dry wood was first put into the furnace, and covered with a considerable quantity of charcoal; over this was laid a stratum of ironstone, and then another of charcoal, and so on until the furnace was quite full. The furnace was a circular tower of clay, about 10 feet in height and 3 in diameter, surrounded in two places with withes, to prevent the clay from cracking and falling to pieces by the violence of the heat. Round the lower part, on a level with the ground, but not so low as the bottom of the furnace, which was somewhat concave, were made seven openings, into each of which were placed three tubes of clay, and the openings again plastered up in such a manner that no air could enter the furnace but through the tubes, by the opening and shutting of which the fire was regulated. The fire was applied through one of the tubes, and blown for some time with bellows made of goat's skin. The operation went on very slowly at first, and it was some hours before the flame appeared above the furnace; but after this it burnt with great violence all the first night, and the people who attended put in at times more charcoal. On the day following the fire was not so fierce, and on the second night some of the tubes were withdrawn, and the air allowed to have free access to the furnace; but the heat was still very great, and a bluish flame rose some feet above the top of the furnace. On the third day from the commencement of the operation all the tubes were taken out, the ends of many of them being vitrified with the heat, but the metal was not removed until some days afterwards, when the whole was perfectly cool; part of the furnace was then taken down, and the iron appeared in the form of a large irregular mass, with pieces of charcoal adhering to it. It was sonorous, and when any portion was broken off, the fracture exhibited a granulated appearance like broken steel."

That the iron ores of Monmouthshire and Gloucestershire were extensively worked by the Romans during the period of their reign in Britain is certain, from the immense beds of iron cinders that have been discovered in the Forest of Dean; it is probable that Bath was the principal seat of their foundries; relics of their operations, in the form of cinders, and coins, have likewise been discovered in Yorkshire and in other counties. During the reign of William the Conqueror, Gloucester was the city where the trade of forging iron was chiefly carried on, the Forest of Dean supplying the ores. It is uncertain when the art of casting was first discovered; cannon are supposed to have been first used in England by Edward the Third, who used them in his invasion of Scotland in 1327, at Cressy, and at the siege of Calais in 1346. These cannons were not however cast, but were constructed on the same principles as coopers construct their barrels; a number of iron bars fitting as close as possible to each other were arranged round a cylinder of wood, and were then bound together by strong iron hoops; the wood being driven out, there remained an iron pipe which formed the barrel. This mode was superseded by *casting* the cannon of bronze.

During the 14th and 15th centuries, iron and steel were imported into this country from Germany, Prussia, and other places, and also iron from Spain; but as several improvements in the manufacture had taken place in the course of this period in England, laws were made towards the conclusion of the 15th century, prohibiting the importation of any of the articles manufactured in this country in iron and steel. During the reign of Elizabeth, the consumption of charcoal by the iron furnaces was so great that it was deemed necessary to enact laws to prohibit the erection of new furnaces, and to prevent the felling of timber for fuel; persons interested in the manufacture of iron were consequently compelled to turn their attention to the finding of some substitute for charcoal, and in the reigns of James the First and Charles the First many attempts were made to smelt iron with pit-coal, but without success; the consequence was the entire abandonment of iron making in many parts of the country, and a great decrease in the manufacture in others; so complete indeed was the failure of all the experiments made to substitute pit coal for charcoal, that all attempts were abandoned till the early part of the next century, when pit-coal was first used (1713) by Mr. Abraham Darby in his furnace at Colebrook Dale; and in the 44th volume of the Philosophical Transactions, published in 1747, it is stated, that "Mr. Ford, from iron and coal, both got in the same Dale (Colebrook), makes iron brittle or tough as he pleases, there being cannon thus cast so soft, as to bear turning like soft iron." Notwithstanding, however, the establishment of the fact that iron ore could be smelted, and iron manufactured with pit-coal, and although great efforts were made, by increasing the column of blast, by the substitution of steam power for that of horses and human labour, there appears to have been a steady and progressive diminution in the quantity of iron produced in this country; and recourse was had to foreign markets, particularly to those of Sweden and Russia, for the necessary and increasing demand. Thus, the imports of iron between the years 1711 and 1776, were as follows:—

			Tons.
1711	to	1718	15,642
1729	„	1735	25,501
1750	„	1755	34,072
1761	„	1766	48,980

In 1740 there were only 59 blast furnaces in work in England and Wales, the total make of which amounted to not more than 17,350 tons, being an average of 294 tons per annum for each furnace, a quantity very little exceeding that sometimes made in a *single week* in some of the furnaces in Wales at the present day.

The earliest contrivance for throwing a powerful and constant blast into the furnace was a forcing pump, worked by a water wheel or by a steam engine; and it appears that the first cylinders, at least of any magnitude, were erected at the celebrated Carron Iron Works in the year 1760 by Mr. John Smeaton. These cylinders were four feet six inches in diameter, exactly fitted with a piston, moved up and down by means of a water wheel; in the bottom of the cylinder was a large valve, like that of a bellows, which rose as the piston was lifted up, and thus admitted the air into the cavity of the cylinder below. Immediately above the bottom was a tube which went to the furnace, and as it proceeded from the cylinder, was furnished with a valve opening outwards. Thus when the piston was drawn up, the valve in the bottom rose and admitted the air that way into the cylinder, while the lateral valve shut, and prevented any air from getting into it through the pipe. When the piston was thrust down, the valve in the bottom closed, while the air, being compressed in the cavity of the cylinder, was violently forced out through the lateral tube into the

furnace. There were four of these large cylinders applied to blow the furnace, and so contrived, that the strokes of the pistons, being made alternately, produced an almost uninterrupted blast. A large column of air, of triple or quadruple density, was thus obtained, and effects equivalent to these great improvements followed. The same furnace that formerly yielded ten and twelve tons weekly now sometimes produced forty tons in the same period, and on the average in one year 1,500 tons of metal (Scrivenor); and such was the impulse given to the trade by this unexpected success of a powerful blast with pit-coal, that in 1788 the manufacture of pig iron in England, Wales, and Scotland amounted to 68,300 tons, being an increase of 50,950 tons on the quantity manufactured previous to the introduction of pit-coal.

A new era in the history of the iron manufacture may be considered to have been established in 1788-90, by the introduction of the double power engine of James Watt, the regular and increased effects of which powerful machine were soon felt in most of the iron districts: the proprietors of furnaces greatly increased their make, and fresh capital was embarked in the trade: in the short period of eight years, the manufacture of pig iron was nearly double, being in the year 1796, (according to the returns sent to the chairman of the committee of the House of Commons, on the subject of the coal trade, when Mr. Pitt had it in contemplation to add to the revenue by a tax upon coal at the pit mouth,) 125,079 tons, from 121 furnaces—104 English and Welsh, and 17 Scotch; the English and Welsh furnaces producing an average of 1,048 tons each per annum, and the Scotch furnaces 946 tons. In 1806, the number of furnaces in blast in Great Britain was 173, and the make 258,206 tons of pig iron, being an increase in ten years of 133,127 tons per annum; of these 162 were coke furnaces, the average produce of each of which had risen to 1,546 tons. In this year great excitement existed in the iron trade, in consequence of the proposal of Lord Henry Petty to levy, as a war tax, a duty of 40*s.* per ton on pig iron; he introduced a bill into the House of Commons having this object, and succeeded in carrying it, notwithstanding a powerful opposition, by a majority of ten members; the measure was however abandoned.

In France, in 1801, the quantity of cast iron produced amounted to 140,000 tons from 550 blast furnaces, of which only one (that of Creusot) was worked with coke. In 1809, a description of the English process of making iron was published by order of council, by M. de Bonnard (an engineer of mines); another engineer of mines (M. de Gallois), after having passed several months in England, established at St. Etienne the second blast furnace in France, wherein the minerals were treated in the same manner as the English, and in which coke was employed; but the difficulties he had to encounter proved a bar to his success, and he is said to have died prematurely from the grief and trouble which the enterprise occasioned him (Scrivenor.) The employment of pit-coal in the manufacture of iron received a very slow development in France, for in 1818 the quantity of cast iron made with coke was very small, and no wrought iron was prepared with pit-coal; in 1824 not more than 3,000 tons of cast iron were made with coke, but in 1828 it had risen to 17,000 tons. Though this did not amount to a tenth of the whole produce, nevertheless the quantity of bars made with pit-coal amounted in this year to 48,000 tons, being nearly one-third of the total manufacture of wrought iron.

Cast iron, using that term in the sense in which it is now understood, must have been wholly unknown to the ancient metallurgists, for even in the smelting of their poorer ores, where they urged their furnaces with the greatest heat they could command, using probably lime as a flux, the reduced metal was allowed to cool in the bed of the furnace, and was never run into pigs as in the modern practice; their best iron was produced in one operation, and after cooling and separating the scoriæ, it was forged at once into tough hard bars under the tilt hammer. The time and fuel consumed in these ancient methods was enormous, and the iron that remained in the scoriæ, amounted to fully one half of the original metallic contents of the ore.

The modern processes of iron smelting differ materially according as the fuel employed is charcoal or pit-coal. As an illustration of the method adopted when the former is used, the following details of the manufacture of the celebrated "Oeregrund iron" may be taken, premising that the operations vary in a few particulars in other countries where different kinds of ore are dealt with. The *oeregrund* iron is made from the magnetic ironstone of Dannemora in Sweden. The ore, in moderately large pieces such as it comes from the mine, is first roasted. For this purpose an oblong coffer of masonry, 18 feet long, 15 feet wide, and about 6 feet in depth, open at top, and furnished with a door at one of its smaller extremities, is entirely filled with logs of wood: over this the ore is piled to the height of from 5 to 7 feet, and is covered with a coating of small charcoal, almost a foot and a half in thickness. Fire is then communicated to the bottom of the pile, by means of the door just mentioned,

and in a short time the combustion spreads through the whole mass; the small quantity of pyrites that the ore contains is decomposed by the volatilisation of the sulphur: the moisture is also driven off, and the ore, from being very hard and refractory, becomes pretty easily pulverisable. In the space of twenty-four hours the roasting is completed: and the ore when sufficiently cool is transferred to a stamping mill, where it is pounded dry, and afterwards sifted through a network of iron, which will not admit any piece larger than a hazel-nut to pass. It is now ready to be smelted. The smelting furnace is a strong quadrangular pile of masonry, the internal form of which, though simple in form, is not very easily described. It may be considered in general as representing two irregular truncated cones, joined base to base; of these the lower is scarcely more than one-third of the upper, and is pierced by two openings, through the upper end of which the blast of wind from the blowing machine is admitted into the furnace; and from the lower the melted matter, both scoriæ and metal, is discharged from time to time at the pleasure of the workmen.

The furnace is first filled with charcoal alone, and well heated, after which alternate charges are added of ore, either alone, or mixed with limestone (if it requires any flux) and charcoal; the blast is let on, and the metal in the ore being highly carbonised in its passage through the upper part of the furnace, is readily melted as soon as it arrives in the focus of the blast, whence it subsides in a fluid state to the bottom of the furnace covered with a melted slag. Part of the clay that closes the lower aperture of the furnace is occasionally removed, to allow the scoriæ to flow out, and at the end of every ninth hour the iron itself is discharged into a bed of sand, where it forms from ten to twelve small pigs. As soon as the iron has flowed out, the aperture is closed again, and thus the furnace is kept in incessant activity during the first six months of the year, the other six months are employed in repairing the furnaces, making charcoal, and collecting the requisite provision of wood and ore. The next process for converting the pig into bar iron is refining: for this purpose a furnace is made use of, resembling a smith's hearth, with a sloping cavity, sunk from ten to twelve inches below the level of the blast-pipe. This cavity is filled with charcoal and scoriæ, and on the side opposite to the blast-pipe is laid a pig of cast iron well covered with hot fuel. The blast is then let in, and the pig of iron being placed in the very focus of the heat, soon begins to melt, and as it liquifies, runs down into the cavity below: here, being out of the direct influence of the blast, it becomes solid, and is then taken out, and replaced in its former position. The cavity being then filled with charcoal, it is thus fused a second time, and after that, a third time, the whole of these three processes being usually effected in between three and four hours. As soon as the iron has become solid it is taken out, and very slightly hammered to free it from the adhering scoriæ: it is then returned to the furnace, and placed in a corner, out of the way of the blast, and well covered with charcoal, where it remains, till, by further gradual cooling, it becomes sufficiently compact to bear the tilt hammer. Here it is well beaten till the scoriæ are forced out, and it is then divided into several pieces, which, by a repetition of heating and hammering are drawn into bars, and in this state is ready for sale. The proportion of pig iron obtained from a given quantity of ore is subject to considerable variation, from the difference in the metallic contents of different parcels of ore and other circumstances; but the amount of bar iron that a given weight of pig metal is expected to yield is regulated very strictly, the workmen being expected to furnish four parts of the former for five parts of the latter, so that the loss does not exceed 20 per cent.

In some parts of America, particularly in the states of Vermont and New Jersey, the *Catalan* forge is extensively employed for smelting the rich magnetic ores which there abound. The form of this fire (which is nearly uniform everywhere), and the manipulation with it in America, is thus described by Overman; —The whole is a level hearth of stone work, from 6 to 8 feet square, at the corner of which is the fireplace, from 24 to 30 inches square, and from 15 to 18, often 20, inches deep. Inside it is lined with cast iron plates, the bottom plate being from 2 to 3 inches thick. *Figure* 993 represents a cross section through the fireplace and tuyere, commonly called tue iron; *d* represents the fire-place, which, as remarked above, is of various dimensions. The tuyere *b* is from 7 to 8 inches above the bottom, and more or less inclined ac-

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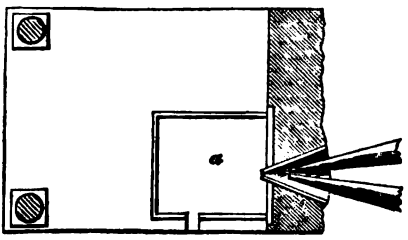
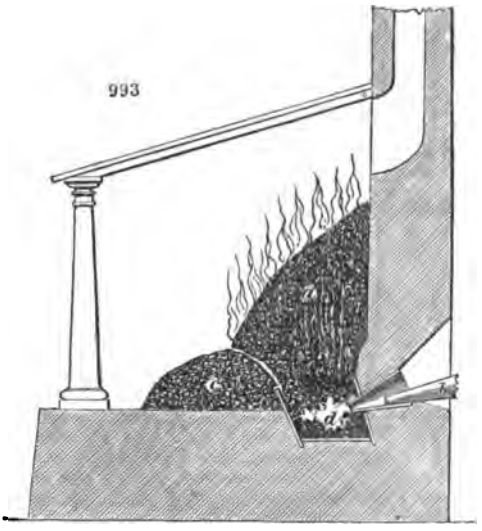


cording to circumstances. The blast is produced by wooden bellows of the common form, or more generally by square wooden cylinders, urged by water wheels. The ore chiefly employed is the crystallised magnetic ore. This ore very readily falls to a coarse sand, and when roasted varies from the size of a pea to the finest grain. Sometimes the ore is employed without roasting. In the working of such fires much depends on the skill and experience of the workman. The result is subject to considerable variation, that is, whether economy of coal or that of ore is our object. Thus a modification is required in the construction either of the whole apparatus or in parts of it. The manipulation varies in many respects. One workman by inclining his tuyere to the bottom, saves coal at the expense of obtaining a poor yield. Another by carrying his tue iron more horizontally at the commencement, obtains a larger amount of iron, though at the sacrifice of coal. Good workmen pay great attention to the tuyere, and alter its dip according to the state of the operation. The general manipulation is as follows: — The hearth is lined with a good coating of charcoal dust; and the fire plate, or the plate opposite the blast, is lined with coarse ore, in case any is at our disposal. If no coarse ore is employed, the hearth is filled with coal, and the small ore piled against a dam of coal dust opposite the tuyere. The blast is at first urged gently, and directed upon the ore, while the coal above the tuyere is kept cool. Four hundred pounds of ore are the common charge, two-thirds of which are thus smelted, and the remaining third, generally the finest ore, is held in reserve, to be thrown on the charcoal when the fire becomes too brisk. The charcoal is piled to the height of two, sometimes even three and four feet, according to the amount of ore to be smelted. When the blast has been applied for an hour and a half, or two hours, most of the iron is melted, and forms a pasty mass at the bottom of the hearth. The blast may now be urged more strongly, and if any pasty or spongy mass yet remains, it may be brought within the range of the blast and melted down. In a short time the iron is revived, and the scoriæ are permitted to flow through the tapping hole *c*, so that but a small quantity of cinder remains at the bottom. By means of iron bars, the lump of pasty iron is brought before the tuyere. If the iron is too pasty to be lifted, the tuyere is made to dip into the hearth; in this way the iron is raised from the bottom, directly before, or to a point above the tuyere, until it is welded into a coherent ball, twelve or fifteen inches in diameter. This ball is brought to the hammer or squeezer, and shingled into a bloom, which is either cut in pieces to be stretched by a hammer, or sent to the rolling mill to be formed into marketable bar iron. A mixture of fibrous iron, cast iron, and steel, is the result of the above process; the quality of the iron depends entirely on the quality of the ore, for there are no opportunities for the exercise of any skill to create improvements in the process; poor ores cannot be smelted at all. In Vermont, where the rich magnetic ores are employed, a ton of blooms costs about 40 dollars; 4 tons of ore, and 300 bushels of charcoal are required to produce 1 ton of blooms. The *Fourneaux à pièce* of the French, or *Stück-ofen* of the Germans, holds a place intermediate between the *Catalan hearth* and the high blast furnace now in general use. The iron produced in this kind of furnace is generally of a very superior kind, but it is very little in use at the present time, on account of the great expense of its manipulation. The *Stück-ofen*, or salamander furnace, as it is sometimes called, is a small cupola, its interior having the form of a double crucible. It is usually from 10 to 16 feet high, and 24 inches wide at bottom and top; and measures at its widest part about 5 feet. There are generally two tuyeres, both on the same side; the breast is open, but during the smelting operation it is shut by bricks. The furnace is heated previous to closing in the breast; after which charcoal and ore are thrown in; the blast is then



turned on; as soon as the ore passes the tuyere, iron is deposited at the bottom of the hearth; when the cinder rises to the tuyere, a portion is suffered to escape through a hole in the dam: the tuyeres are generally kept low upon the surface of the melted iron, which thus becomes whitened: as the iron rises the tuyeres are raised. In about 24 hours *one ton* of iron is deposited at the bottom of the furnace, the blast is turned off, and the iron, which is in a solid mass, in the form of a salamander, or *Stück wolf*, as the Germans call it, is lifted loose from the bottom by crowbars, taken by a pair of strong tongs, which are fastened on chains, suspended on a swing crane, and then removed to an anvil, where it is flattened by a tilt hammer into four-inch thick slabs, cut into blooms, and finally stretched into bar iron by smaller hammers. Meanwhile the furnace is charged anew with ore and coal, and the same process is renewed. This process, as well as that of the Catalan hearth, is impracticable with ores containing much foreign matter, or less than 40 per cent. of metal.

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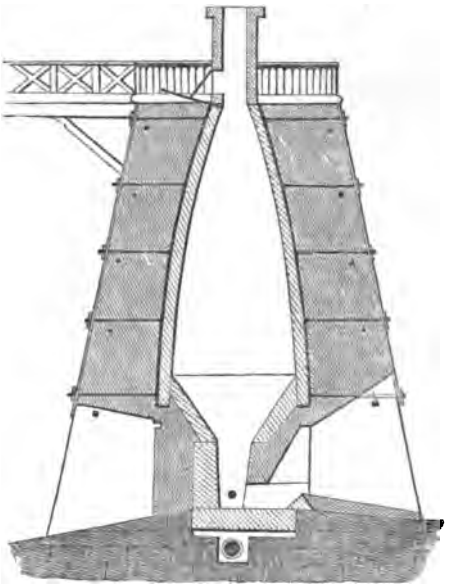

The general form of the modern charcoal blast furnace, as used in the United States, where this fuel is far more common than pit-coal (indeed, it is doubtful whether any coke furnaces are at the present time in operation in that country), is shown in vertical section in *fig.* 994, and in section through the tuyere arches in *fig.* 995. The ores designed to be smelted in this furnace are hydrated oxides of iron, such as brown hæmatite, brown iron stone, pipe ore, and bog ores. The height is 35 feet; hearth from base to the boshes, 5 feet, 6 inches; width at the bottom, 24 inches; and at top, 36 inches. The tuyeres are 20 inches above the base. The boshes are 9 feet 6 inches in diameter, and measure from the top of the crucible 4 feet, which gives about 60° slope. The blast is conducted through sheet-iron or cast-iron pipes laid below the bottom stone into the tuyeres. The top is furnished with a chimney, by which the blaze from the tunnel head is drawn off. Around the top is a fence of iron or wood. *Fig.* 996 shows the method of preparing and arranging the hearth-stones. *d* is the bottom stone, made of a fine close-grained sandstone, from 12 to 15 inches thick, at least 4 feet wide, and 6 feet long; it reaches underneath at least half of the dam-stone *b*. This bottom stone is well bedded in fire-clay, mixed with three-fourths sand. After the bottom stone is placed, the upper part of which must be three-fourths of an inch lower at the dam-stone than at the

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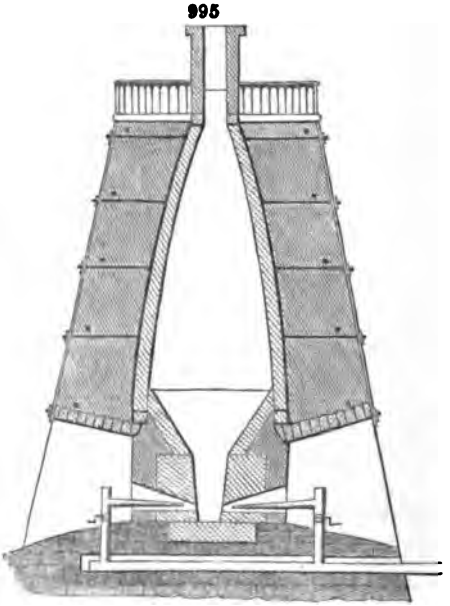

back, the two side stones *c*, are laid embedded in fire-clay. These stones must be at least 6 feet and a half long, reaching from 18 inches behind the crucible to the middle of the dam-stone. Their form is most commonly square, that is, a prism of four equal sides; the transverse section of the grain must be in all cases placed towards the fire; the side stones are sometimes square, but oftener bevelled according to the slope of the hearth. Upon these stones the tuyere stones *d* are bedded; the latter suffer much from heat, and therefore ought to be of the best quality. They should be from 20 to 24 inches square, or even larger: the tuyere holes *f*, a kind of taper arch, are cut out before the stones are bedded. These stones do not reach further than to the front or timpstone *g*, and are therefore scarcely four feet long; the top stone *e*, is generally sufficiently high to raise at once the crucible to its destined height. After both sides are finished the back stone *l* is put in, and then the timpstone, *g*; the space between the hearthstones and the rough wall of the furnace stack is filled and walled up with common brick or stones.

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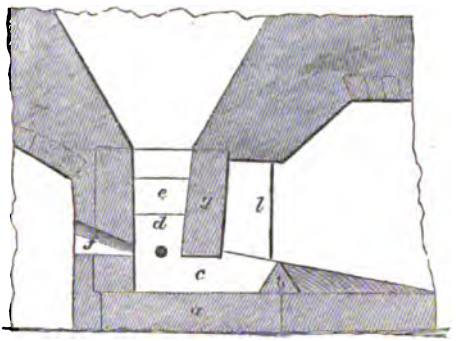

In starting a charcoal furnace, it is first thoroughly dried by burning a fire for several weeks in the interior, which has a temporary lining of bricks. The lower part of the furnace or the hearth is then filled gradually with charcoal, and when the fuel is well ignited, and the furnace half filled, ore may be charged in; it is sometimes advisable to increase the draught by forming grates by laying across the timp a short iron bar, as high up as the dam-stone, by resting upon this bar six or seven other bars or ringers, and by pushing their points against the back stone of the hearth. There is not much iron made during the first 24 hours; most of the ore is transformed into slag, and the iron which comes down gets cold on the bottom stone, where it is retained; the blast should not be urged too fast at first, but increased gradually, in order to avoid the serious evil arising from a cold hearth; if all goes on well the hearth will be free from cold iron or clinkers in a week, the yield of iron will increase, and the burden may be increased likewise. The average charge of charcoal, which should be dry, coarse, and hard, is about 15 bushels. According to Overman's experience, the most favourable height for a charcoal furnace is 35 or 36 feet; if below this standard they consume too much fuel, if above they are troublesome to work; if it be desired to enlarge the capacity of a furnace, he thinks it better to increase the diameter of the boshes, or to curve the vertical section. There is much difference of opinion amongst managers of furnaces on the subject of the proper size for the throat of the furnace; the tendency of narrow throats would seem to be to consume more coal than wide ones, inasmuch as in Pennsylvania and throughout the whole west, where narrow tops are preferred, the consumption of charcoal per ton of iron is from 160 to 180 bushels, while in the state of New York, and further east, where the furnace throats are wider, the consumption is from 120 to 130 bushels. Another subject which demands the strictest attention is the regulation of the blast. A weak soft charcoal will not bear a much greater pressure than from half a pound to five-eighths of a pound to the square inch; strong coarse charcoal will bear from three quarters of a pound to a pound; and again, it may be laid down as a rule that the larger the throat in proportion to the boshes, the stronger ought to be the blast, and that a narrow top and wide boshes, while they permit a weaker blast, involve the loss of much fuel. In every case a careful roasting of the ores at charcoal furnaces will prove advantageous; this is the surest means of saving coal and blast, and of avoiding many annoyances in the working of the furnace.

With regard to hot blast, as applied to charcoal furnaces, Overman remarks, that under some circumstances it might be advantageous, but in others it is decidedly injurious; that it is, at least, a questionable improvement, and it may be doubted whether the manufacture of bar iron has derived any benefit from it; *qualitatively* it has not. Hot blast is quite a help to imperfect workmen: it melts refractory ores, and delivers good foundry metal with facility.

English process of iron making.— Mr. Hunt, in his very valuable "Mineral Statistics," gives us the total quantity of pig iron produced in Great Britain in the year 1858; — 3,456,064 tons, as follows: —

	Tons.
Northumberland	45,312
Durham	265,184
Yorkshire, North Riding	189,320
Do. West Riding	85,936
Derbyshire	131,577
Lancashire	2,840
Cumberland	26,264
Shropshire	101,016
North Staffordshire	135,308
South Staffordshire and Worcestershire	597,809
Gloucestershire	23,530
Northamptonshire	9,750
Wilts and Somerset	2,040
North Wales	28,150
South Wales	886,478
Scotland	925,500
	3,456,064

The number of furnaces in blast to furnish this astonishing make are, in England, 332, distributed over 162 iron works; in Wales, 153, distributed over 57 works; and in Scotland, 133, over 32. To supply these furnaces there were raised 8,040,959 tons of ore, the estimated value of which, at a mean of 11*s.* per ton, is 4,422,527*l.*; that of the pig iron, at a mean money value of 4*l.* a ton, being 13,824,256*l.* Of the ironstone 1,650,000 tons were argillaceous carbonate from the coal measures of Staffordshire and Worcestershire; nearly 1,500,000 tons from the coal measures of North and South Wales; and 2,212,250 tons argillaceous carbonate from Scotland. The annual production of pig iron over the whole world was estimated by Mr. Blackwell, in December, 1855, as follows:—

	Tons.
Great Britain	3,000,000
France	750,000
United States of America	750,000
Prussia	300,000
Austria	250,000
Belgium	200,000
Russia	200,000
Sweden	150,000
Various German States	100,000
Other countries	300,000
	6,000,000

From which it appears that the quantity of iron made annually in this island alone, is nearly, if not quite, as large as the total quantities produced in all other countries. The nature of the ore which forms the staple supply of the English furnaces (argillaceous carbonate), and the universal adoption of coke and coal as fuel, have led by necessity to a method of manufacture of iron quite peculiar to this country, and wholly inapplicable to those establishments that are carried on by means of charcoal. We shall proceed to describe the various steps of this manufacture in detail:—and first,

Of the blast furnace.—The blast furnaces at present in use are of various sizes, being from 35 to 60 feet in height, and at the *boshes*, or widest part, from 12 to 17 feet. The internal form commonly adopted consists essentially of two frustrums of cones meeting each other at their bases, at the point where the widest part or the top of the boshes is situated. From this point the furnace gradually contracts both upwards to its mouth, and downwards to the level of the tuyeres below. The hearth, properly speaking, is that part of the furnace only which receives the fluid metal and cinder, as they fall below the level of the tuyeres. It forms a short prolongation from that point of the lower inverted cone. From the boshes upward the width gradually decreases to the tunnel head, which varies from 7 to 9 feet in diameter, according to the size of the furnace. The hearth is generally a cube, from 2½ to 3 feet square. The air is introduced by one, two, or three small apertures, called *tuyeres*.

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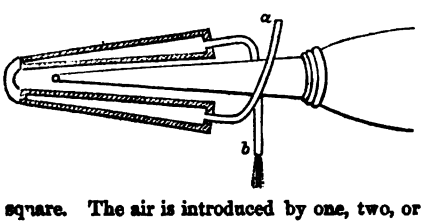

When two tuyeres are used, the orifices of their blowpipes are about three inches in diameter, and the pressure of the blast is from 2½ to 3 lbs. on the square inch. To prevent the tuyeres from being melted by the intense heat to which they are exposed, a stream of cold water is caused constantly to flow round their nozzles by an arrangement which will be immediately understood by an inspection of *fig.* 997, which represents a section of a tuyere nozzle thus protected, the cold water entering the casing by the tube *a*, and the hot water running off by the tube *b*. The upper part of the furnace above the boshes is called the *cone* or *body*. It is formed by an interior lining of fire-brick, about 14 inches in thickness, between which and the exterior masonry is a casing of fine refractory sand compactly rammed in, air holes being left for the escape of aqueous vapour. In the base of the furnace four arches are left, the back and sides are called *tuyere houses*, the front is called the *cinder fall*; the bottom of the furnace is formed either of large blocks of coarse sandstone or of large fire-bricks. The materials are charged into the furnace through the tunnel head, which is provided with one or more apertures for the purpose. The general form of a blast furnace is shown in *fig.* 998, and the following measurements represent the interior structure of two that worked well:—

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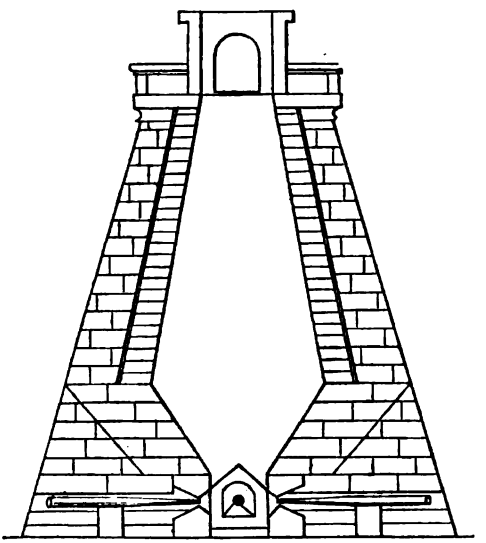

	No. 1.	No. 2.
Height from the hearth to the throat or mouth	45	49
Height of the crucible or hearth	6½	6
„ of the boshes	8	7
„ of the cone	30½	36
„ of the chimney or mouth	8	12¾
Width of the bottom of the hearth*	2½	2
„ at its upper end	3	2⅜
„ of the boshes†	12⅜	13⅛
„ at one-third of the belly	12	11½
„ at two-thirds of ditto	8½	9⅛
„ at mouth	4½	3⅜
Inclination of the boshes‡	59°	52°

Fig. 999 represents the hearth and boshes in a vertical side section. *a* is the *tymp* stone, and *b* the tymp plate, for confining the liquid metal in the hearth. The latter is wedged firmly into the side walls of the hearth; *c* is the dam-stone, which occupies the whole breadth of the bottom of the hearth, excepting about six inches, which space, when the furnace is at work, is filled before every cast with a strong binding sand. This stone is faced outside by a cast-iron plate *d*, called the *dam* plate, of considerable thickness and peculiar shape. The top of the dam-stone, or rather the notch of the dam-plate, lies from 4 to 8 inches under the level of the tuyere hole. The space under the tymp plate, for 5 or 6 inches down, is rammed full for every cast with a strong loamy earth or even fine clay, a process called tymp stopping.

* The width of the hearth differs greatly in the furnaces in different localities. In Scotland it varies from 6 to 8 feet; in the Welsh furnaces from 5 to 8 feet. When coke is used as fuel Mr. Truran thinks 6 feet a sufficient width for all purposes; but with coal, with full-sized furnaces, 16 to 19 feet across the boshes, he thinks a 7 feet hearth to be more advantageous.

† The diameter of the boshes in some of the Welsh furnaces is as much as from 18 to 19 feet.

‡ The angle with which the boshes rise in different furnaces varies from 50° to 80°. Mr. Truran thinks that when the full smelting power of the furnace is desired, the angle should not be less than 70°, which is about that of the Scotch furnaces.

The blowing machines employed in Staffordshire are generally cast-iron cylinders, in which a metallic piston is exactly fitted as for a steam engine, and made in the same way. Towards the top and bottom of the blowing cylinders orifices are left covered with valves, which open inside when the vacuum is made with the cylinders, and afterwards shut by their own weight. Adjutages conduct into the iron globe or chest the air expelled by the piston, both in its ascent and descent, because these blowing machines have always a double stroke.

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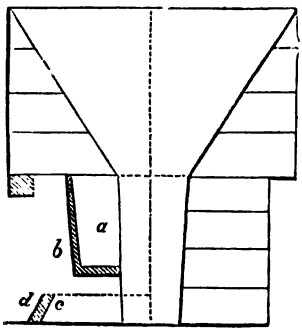

The pressure of the air is made to vary through a very considerable range, according to the nature of the fuel, and the season of the year: for as in summer the atmosphere is more rarefied it must be expelled with a compensating force. The limits are from 1½ to 3½ pounds on the inch, the average in Staffordshire being 3 lbs. The orifices, or nose pipes through which the air issues, also vary with the nature of the coke and the ore.

In a blast apparatus employed at the Cyfartha works, moved by a 90 horse steam power the piston rod of the blowing cylinder is connected by a parallelogram mechanism with the opposite end of the working beam of the steam engine. The cylinder is 9 feet 4 inches diameter, and 8 feet 4 inches high. The piston has a stroke 8 feet long, and it rises 13 times in the minute. By calculating the sum of the space percursed by the piston in a minute, and supposing that the volume of the air expelled is equal to only 96 per cent. of that sum, we find that 12,588 cubic feet of air are propelled every minute. Hence a horse power applied to blowing machines of this nature gives on an average 137 cubic feet of air per minute.

At the establishment of Cyfartha for blowing seven smelting furnaces, and the seven corresponding fineries, three steam engines are employed, one of 90 horse power, another of 80, and a third of 40, which constitute on the whole a force of 210 horses, or 26 horses and ¼th per furnace, supposing the fineries to consume one-eighth of the blast. In the whole of the works of Messrs. Crawshay, the proprietors of Cyfartha, the power of about 340 horses is expended in blowing 12 smelting furnaces and their subordinate fineries; which gives from 25 to 26 horses for each, allowing as before ¼th for the fineries. Each of the furnaces consumes about 3,567 cubic feet of air per minute.

The form of the blast furnace from the boshes to the throat is exhibited in *fig.* 998 as a truncated cone, and such was formerly invariably the construction; of late years however considerable variations have been introduced. In Scotland the body of the furnace frequently is carried up cylindrical, or nearly so, for a considerable height, terminating with the usual truncated cone to the mouth; in other places a curved line is substituted for a straight one. The form adopted in some furnaces recently erected at Ebbw Vale and Blaina is shown in *fig.* 1000.

The diameter of the throat or filling place is a subject of very great importance to the operations of the furnace. Most iron masters are, we believe, agreed as to the impolicy of the narrow tops formerly adopted; the waste of fuel in such furnaces, where the width of the throat scarcely averaged one-fourth of the diameter of the furnace, was very great, the average yield of coal to the ton of crude iron exceeding 6 tons; by enlarging the throat to one-third, the consumption of coal was reduced to 4 tons, and by continuing the enlargement to one-half it was reduced to 2 tons. Mr. Truran states that on reducing the diameter of the throat of a furnace at Dowlais from 9 feet to 6, the make of pig iron weekly fell off from 97 tons, to an irregular make of from 50 to 70 tons; and that while with the 9 feet throat the consumption of coal was 45 cwts. to the ton of iron, it rose with the 6 feet throat to 70, 80, and 90 cwts., the quality of the iron being exceedingly bad. On enlarging the throat to 9½ feet, the make, for a period of 6 months, averaged over 160 tons, with a good yield of coal and other materials. Mr. Truran appears to question the utility of reducing the diameter of the furnace at the top, which was only adopted in the first place from an erroneous impression that the furnace could be filled best through a contracted mouth; but it may be questioned whether this widening of the throat may not be carried too far, so as to disperse the heated gases too rapidly, and whether a diameter much greater than one-half of the largest dimensions of the furnace above the boshes can with utility be adopted. On this subject Mr. Kenyon Blackwell says, "If that part of the blast

furnace commencing at the point where it attains its greatest width were continued of the same wide dimensions upwards to its mouth, two objectionable results would ensue: first the upper part of the furnace would be cooled by the too rapid dispersion of the ascending column of heated gases, and by the entire absence of the reverberating effect of the contracted mouth; and secondly, the materials could not be equally spread from the filling holes over so wide a surface. The diameter of the upper part furnace ought, therefore, to be such as will cause the materials thrown in at the filling holes to distribute themselves equally in their descent over every part of the sectional area of the furnace, and will produce such a reverberation only of heat as shall be sufficient to expel the water and carbonic acid contained in the materials, without consuming any of the carbon of the fuel, which ought to remain intact until it reaches the lower regions of the furnace, where it is vaporised as carbonic oxide, and produces the reactions on which the reduction of the ore depends."

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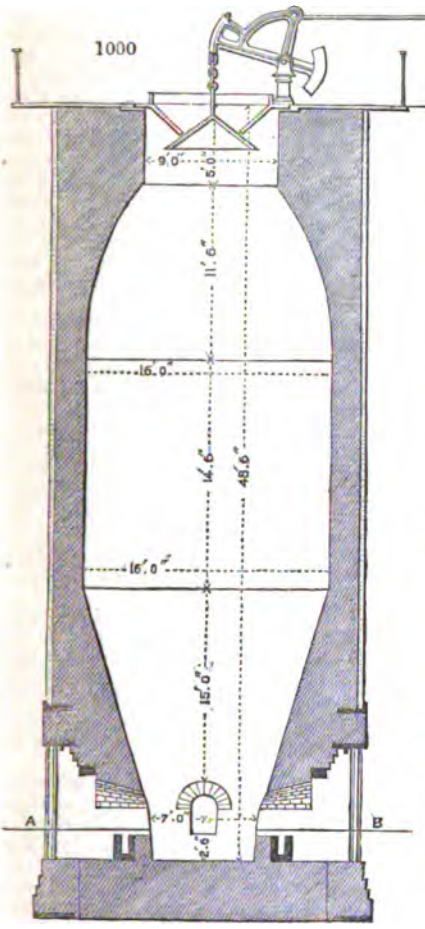

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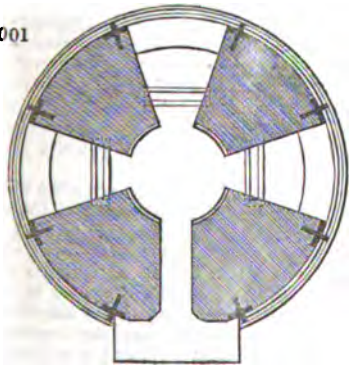

Calcination of the ironstone. — This is effected either in kilns, or in the open air; the object being to separate carbonic acid, water, sulphur, and other substances volatile, at a red heat. The operation is performed most effectually, and probably at the smallest cost, in kilns. The interior shape of the calcining kilns differs in different works, but they may all be reduced to that of the common lime kiln. A coal fire is first lighted at the bottom of the kiln, and the ironstone is placed over and around, until the floor is covered with red hot ore; a fresh layer of ironstone, with about 5 per cent. of coal, is then laid on, to the depth of 8 or 9 inches; and when this is red hot, a second layer is added, and so on gradually till the kiln is filled; by the time this is done, the lowermost layer is cold and fit to draw, so that the working of the kiln is a continuous operation. When the ore is calcined in the open air, a heap mingled with small coal (if necessary), is piled up over a stratum of larger pieces of coal, the heap being 5 or 6 feet high, by 15 or 20 broad. The fire is applied at the windward end, and after it has burnt a cer-

tain way, the heap is prolonged at the other extremity, as far as the nature of the ground, or the convenience of work requires. From the impossibility of regulating the draught, and from exposure to the weather, the calcination of ore cannot be so well performed in the open air as in kilns; and as to the relative cost of the two methods. Mr. Truran calculates that the quantity of coal per ton of ore is, in the kiln, one hundred-weight of small; and in the open air, two hundred-weights of small, and a half hundred-weight of large; and that while the cost of filling the kiln is barely a penny per ton, that of stacking the heaps on the open air plan, and watching them during the period they are under fire, amounts to fourpence per ton. Against this must, however, be placed the cost of erecting the kiln, which according to the same authority amounts, for a kiln of a capacity equal to 70 tons of argillaceous ore, which will calcine 146 tons weekly, to 160*l*. The ironstone loses by calcining from 25 to 30 per cent. of its weight; it has undergone a remarkable change by the operation; in the raw state, it is a grey or light brown stony looking substance, not attracted by the magnet; after calcination it has a dry feel, adheres strongly to the tongue, is cracked in all directions, is of a light reddish colour throughout, and acts powerfully on the magnet. It should be carried to the furnace as soon as possible, or if kept should be carefully protected from the rain.

Flux.—The only flux that is used in the blast furnace is *limestone*, either in the state of carbonate as it comes from the quarry, or calcined in kilns, by which it is deprived of water and carbonic acid. The lowest bed of the coal formation usually rests on limestone, and in the coal formation itself are found not only the ore and its most appropriate fuel, but the pebbly grits which afford the blocks of refractory stone necessary for building those parts of an iron furnace that are required to endure the utmost extremity of heat, as well as those seams of refractory clay, of which the fire-bricks are composed, with which the middle and upper parts of the furnace are lined. "Thus many situations in this favoured island may be pointed out, in which all the above mentioned materials occur almost on the same spot; and when to this is joined the convenience of water carriage, as happens in many places, that man must indeed be of an obtuse understanding and a churlish temper in whom this wise arrangement and prodigal beneficence of nature fails to produce corresponding feelings." —*Aikin.*

The composition of the limestone to be used in smelting operations is of considerable importance; where calcareous ores are used, the presence of silicic acid in the limestone is advantageous; if clay ores are the main material from which iron is manufactured, a magnesian limestone is preferable, but an aluminous limestone should be used where siliceous ore predominates. Chemical analysis alone can determine to which class a particular limestone belongs, as there is often nothing in the external appearance by which a pure limestone may be distinguished from one containing 40 or 50 per cent. of foreign matter.

Carbonised pit-coal or coke was, till within the last twenty-five years, the sole combustible used in the blast furnace. Coal is coked either in the open air or in kilns. In the former, as practised in Staffordshire, the coal is distributed in circular heaps about 5 feet in diameter by 4 feet high, and the middle is occupied by a low brick chimney piled with loose bricks, to open or to leave interstices between them, especially near the ground. The larger lumps of coal are arranged round this chimney, and the smaller ones towards the circumference of the mass. When everything is adjusted a kindling of coals is introduced into the bottom of the brick chimney, and, to render the combustion slow, the whole is covered with a coat of coal dross, the chimney being loosely covered with a slab of any kind. Openings are occasionally made in the crust, and afterwards shut up, to quicken and retard the ignition at pleasure during its continuance of twenty-four hours. Whenever the carbonisation has reached the proper point for forming good coke the covering of coal dross is removed, and water is thrown on the heap to extinguish the combustion, a circumstance deemed useful to the quality of the coke. In this operation in Staffordshire coal loses the half of its weight, or two tons of coal produce one of coke.

In order to prepare larger quantities of coke at once, long ridges are often substituted for circular heaps, the length of which varies with circumstances and the consumption of coke; they sometimes extend to the length of 200 feet. On erecting one of these ridges a string is stretched along the coking station, in the direction of which large pieces of coal are placed slanting against each other, leaving a triangular space between them, so that a longitudinal channel (ignition passage) is formed through which the string passes. In arranging the pieces it is necessary to pay attention to the natural stratification of the coals, which should be at right angles to the longitudinal direction of the ridge. Parallel with the first series of coals is placed a second, and

then a third, and so on; but the pieces constantly diminish in size until the station measures 6 feet on both sides. Upon this substructure the heap is then made, without particular care in the arrangements, the largest pieces below and the smallest above, until it has reached a height of about 3 feet. To facilitate the ignition, stakes are rammed in at distances of 2 feet from each other, projecting above throughout the whole length of the ridge, which, when subsequently removed, leave vacant spaces for the introduction of burning coal. The ridge, being thus kindled at more than 100 distinct spots, soon breaks out into active combustion. As soon as the burner observes the thick smoke and flame cease at any one part, and a coating of ash making its appearance, he endeavours immediately to stop the progress of the fire by covering it with powdered coal dust, repeating the operation until the whole ridge is covered, when it is left two or three days to cool; the covering on the side exposed to the wind should be thicker and increased in stormy weather. When the fire is nearly extinguished, which occurs in two or three days, the coke is drawn. This mode of coking is simple, but not very economical. The fire proceeding from the upper part of the ridge in a downward direction, towards the lower and interior parts, converts the coal in the upper strata into coke before that in the interior has acquired the temperature necessary for charring, and is still in want of a supply of air, which can only be furnished from without, and must not be excluded by a covering. During the time, therefore, that the inner parts of the heap are being converted into coke, the outer portions are being uselessly, though unavoidably, consumed. For further details concerning coking see the articles COAL and COKE.

The "blowing in" of a coal blast furnace is an operation which requires much care and experience. A fire of wood is first lighted on the hearth; upon this is placed a quantity of coke, and when the whole is well ignited, the furnace is filled to the throat with regular charges of calcined ore, limestone, and coke, and the blast, which should at first be moderate, is turned on. At the works around Merthyr Tydvil, the first charges generally consist of 5 cwts. of calcined argillaceous ore and 1¾ cwt. limestone, to 4 cwts. of rich coke; this burden is kept on for about 10 days, it is then increased to 6 cwts. of calcined ore and 2½ cwts. of limestone (*Truran*). The cinders usually make their appearance in about 12 hours after blowing, the metal follows in about 10 hours after, collecting in the hearth to the amount of 3 or 3½ tons in 60 hours after blowing. If all goes on well about 22 tons of metal will be produced in the first week, 38 tons in the second, 55 in the third, and nearly 80 in the fourth; after 10 or 12 weeks the produce will average 110 tons. By forcing the furnace in its infancy a much greater produce of iron may be obtained, though to the injury of its subsequent working. Mr. Truran relates the following case in point. A furnace was blown in at the Abersychan works with such volumes of blast and rich burden of materials that a cast of several tons was obtained within 14 hours after applying blast. The first week's blowing produced 200 tons, at which rate it continued for two or three weeks, when it rapidly diminished, falling so low as 19 tons for one week's make. From this deplorable state it was made to produce 26 tons, and, after considerable delay, 100 tons; but with a large increase in the yield of materials over that at the other furnaces. When a furnace is first blown in it should be made to produce grey iron; but the tendency of forcing is to produce a white iron with a dark scouring cinder.

The quantity of air thrown into a blast furnace in full work is enormous, exceeding in weight the totals of all the soiled materials used in smelting. A furnace working on foundry iron of a capacity of 275 yards receives 5390 cubic feet of air per minute, which amounts weekly to 1695 tons; when working on white iron a larger volume of blast is employed, averaging 7370 cubic feet per minute, or 2318 tons per week.

The disorders to which blast furnaces are liable have a tendency to produce white cast iron. The colour of the slag or scoriæ is the surest test of these derangements, as it indicates the quality of the products. If the furnace is yielding an iron proper for casting into moulds, the slag has an uniform vitrification and is slightly translucid. When the dose of ore is increased the slag becomes opaque, dull, and of a greenish yellow tint, with blue enamelled zones. Lastly, when the furnace is producing white metal, the slags are more or less black and glossy. The scoriæ from a coke are much more loaded with lime than those from a charcoal blast furnace. This excess of lime appears adapted to absorb and carry off the sulphur which would otherwise injure the quality of the iron. From numerous analyses we have made of blast furnace cinders we select the following as illustrating their general composition under different conditions of the furnace.

Analyses of Blast Furnace Cinders. (Dr. Noad.)

	I.	II.	III.	IV.	V.	VI.	VII.
Silica	40·20	38·49	41·12	40·50	49·40	40·56	42·96
Alumina	17·00	14·12	22·00	12·48	21·08	27·33	20·20
Lime	30·34	34·35	29·48	26·55	17·56	10·30	10·19
Magnesia	7·16	6·14	1·88	3·20	4·96	2·75	2·90
Protoxide of manganese	traces	1·54	traces	11·20	1·04	2·00	1·53
Protoxide of iron	1·90	2·10	3·60	3·20	3·60	13·12	19·80
Potash	1·26	1·48	not determined	1·15	·87	1·90	1·10
Sulphuret of calcium	1·70	1·16	1·09	2·20	1·49	·46	1·32
Loss	·43	·62	·83	·52		1·58	
	100·00	100·00	100·00	100·00	100·00	100·00	100·00

I. Mean of four analyses of grey iron cinders from a furnace at Blaina, South Wales. II. Mean of four analyses of grey iron cinders from an iron work in Staffordshire. III. Mean of four analyses of grey iron (cold blast) cinders from Pontypool, South Wales. IV. Mean of four analyses of green cinder from a furnace at Ebbw Vale, Monmouthshire, smelting spathose ore. V. Mean of four analyses of blast furnace cinders from Sweden. VI. Mean of four analyses of white iron cinder from a furnace at Cwm Celyn Iron Works, Monmouthshire. VII. Mean of four analyses of white iron cinder from the same works, the furnace "scouring."

The following table exhibits the "yields" of materials per ton on the iron made in various works. During the month ending July 25th, 1857, there were consumed in four furnaces at Ebbw Vale 1354 tons 14 cwt. of coke; 1792 tons of coal; 2440 tons 19 cwt. of calcined mine; 1818 tons 10 cwt. of red ore; 1347 tons 6 cwt. of calcined cinders; and 1226 tons 7 cwt. of burnt lime. The quantity of pig iron made was 2305 tons 7 cwt.:—

Yields of Materials per Ton of Iron.

	I.	II.	II.	IV.	V.	VI.	VII.	VIII.	IX.
	cwt.	cwt.	cwt.	cwt.	cwt.	cwt.	cwt.	cwt.	cwt.
Calcined mine	48	28	0	46	33	27	21	37½	49½
Hæmatite	0	10	10	0	0	10	15½	7½	9½
Cinders	0	10	25	0	0	0	11½	11½	0
				coke		coke			
Coal	50	42	36	34	40	34	24		
Limestone	17	14	16	16	5	15	13	4½	18½

I. Dowlais foundry iron. II. Dowlais forge iron. III. Dowlais inferior forge iron. IV. Hirwain foundry iron. V. Dundyvan, Scotland, foundry iron. VI. Pontypool cold blast foundry iron. VII. Ebbw Vale forge iron. VIII. Cwm Celyn forge iron. IX. Coalbrook Vale foundry iron.

The "cinders" mentioned in the foregoing table are not those from the blast furnace, but are derived from the cast iron during the processes of "refining," "puddling," &c., by which the cast iron is converted into wrought iron. These cinders are very rich in iron, which exists in them principally in the form of silicate of the protoxide. They often occur beautifully crystallised, particularly after they have been calcined, an operation which is always performed on them in well conducted works, and which has for its object the removal of the sulphur and the peroxidation of a portion of the iron. These cinders, though very rich in iron, are always contaminated to a considerable extent with both sulphur and phosphorus, as might be expected, seeing that they are the results of operations which have for their objects the removal of the foreign matters contained in the pig iron. The tendency of the former is to make the metal what is called "hot short," so that it cannot be worked while hot under the hammer; the tendency of the latter element is to make the iron "cold short," so that it breaks when an attempt is made to bend it when cold. The separation of sulphur is very perfectly effected by the calcination of the cinder, and it is interesting to trace the progress of its gradual elimination. In some parts of the heap (which often contains several thousand tons of cinder) large masses of prismatic crystals of pure sulphur may be found, but usually nearly the entire surface of the heap is covered with a thin layer of sulphate of iron, sometimes crystallised, but generally in various stages of decomposition; lower down in the heap, where the heat is greater, the sulphate of iron disappears, and in its place red oxide of iron, without a trace of sulphur, is found. In calcining a heap of cinders care is required not to allow the heat to rise too high, or immense masses will become melted together, involving the necessity of blasting, which entails much expense. After the heap has been burning for some months, streams of water are directed over the surface, by

which much soluble sulphate of iron is removed. Unfortunately, the process of calcination does not remove any of the phosphoric acid, which necessitates a judicious employment of these cinders in the blast furnace. We have repeatedly submitted "forge cinders" to analysis, and give in the following table the average results of our experiments.

Analyses of Forge Cinders. (Dr. Noad.)

	I.	II.	III.	IV.	V.	VI.
Silica - - -	6·000	6·67	32·000	15·300	12.300	12·800
Protoxide of iron -	63 750	72·60	52·200	51·720	67·360	10·500
Peroxide of iron -	11·420	6·30	5·000	19·980	2·850	70·000
Sulphuret of iron -	5·766	4·56	1·953	5·396	5·600	·620
Oxide of manganese -	1·680	1·77	not determined	·960	not determined	1·140
Alumina - -	2·400	2·22	9·600	1·300	5·600	·427
Lime - - -	1·232	·12	traces	·420	traces	traces
Magnesia - -	traces	traces	traces	traces	traces	traces
Phosphoric acid -	7·268	5·36	·252	4 140	6 320	4·500
	99·516	99·60	101·105	99·216	100·030	99·987

I. Tap cinder from refined metal. II. Tap cinder from puddling furnace. III. Cinder from re-heating furnace. IV. Mixed cinder from the heap after a few days' burning. V. Cinder squeezed out of the puddled bar during the process of shingling. VI. Specimen from a large heap of thoroughly calcined cinder.

Hot blast. — One of the greatest improvements ever made by simple means in any manufacture, is the employment of hot air instead of the ordinary cold air of the atmosphere, in supplying the blast of furnaces for smelting and founding iron. The discovery of the superior power of a hot over a cold blast in fusing refractory lumps of cast iron, was accidentally observed by Mr. James Beaumont Neilson, engineer to the Glasgow Gas Works, about the year 1827, at a smith's forge in that city, and it was made the subject of a patent in the month of September in the following year. No particular construction of apparatus was described by the inventor by which the air was to be heated, and conveyed to the furnace; but it was merely stated that the air may be heated in a chamber or closed vessel, having a fire under it, or in a vessel connected in any convenient manner with the forge or furnace. From this vessel the air is to be forced by means of a bellows into the furnace. The quantity of surface which a heating furnace is required to have for a forge, is about 1,260 cubic inches; for a cupola furnace, about 10,000 cubic inches. The vessel may be enclosed in brickwork, or fixed in any other manner that may be found desirable, the application of heated air in any way to furnaces or forges, for the purposes of working iron, being the subject claimed as constituting the invention.

Wherever a forced stream of air is employed for combustion, the resulting temperature must evidently be impaired by the coldness of the air injected upon the fuel. The heat developed in combustion is distributed into three portions; one is communicated to the remaining fuel; another is communicated to the azote of the atmosphere and to the volatile products of combustion; and a third to the iron and fluxes, or other surrounding matter, to be afterwards dissipated by wider diffusion. This inevitable distribution takes place in such a way, that there is a nearly equal temperature over the whole extent of a fire-place, in which an equal degree of combustion exists.

We thus perceive that if the air and the coal be very cold, the portions of heat absorbed by them might be very considerable, and sufficient to prevent the resulting temperature from rising to a proper pitch; but if they were very hot they would absorb less caloric, and would leave more to elevate the common temperature. Let us suppose two furnaces charged with burning fuel, into one of which cold air is blown, and into the other hot air, in the same quantity. In the same time, nearly equal quantities of fuel will be consumed with a nearly equal production of heat; but notwithstanding this, there will not be the same degree of heat in the two furnaces, for the one which receives the hot air will be hotter by all the excess of heat in its air above that of the other, since the former air adds to the heat while the latter abstracts from it. Nor are we to imagine that by injecting a little more cold air into the one furnace, we can raise its temperature to that of the other. With more air indeed we should burn more coals in the same time, and we should produce a greater quantity of heat, but this heat being diffused proportionally among more considerable masses of matter, would not produce a greater temperature; we should have a larger space heated, but not a greater intensity of heat in the same space.

Thus, according to the physical principles of the production and distribution of heat, fires fed with hot air should, with the same fuel, rise to a higher pitch of tem-

perature than fires fed with common cold air. This consequence is independent of the masses, being as true for a small stove which burns only an ounce of charcoal in a minute, as for a furnace which burns a hundred-weight; but the excess of temperature produced by hot air cannot be the same in small fires as in great, because the waste of heat is usually less the more fuel is burned.

This principle may be rendered still more evident by a numerical illustration. Let us take, for example, a blast furnace, into which 600 cubic feet of air are blown per minute; suppose it to contain no ore but merely coal or coke, and that it has been burning long enough to have arrived at the equilibrium of temperature, and let us see what excess of temperature it would have if blown with air of 300° C. (572° F.), instead of being blown with air at 0° C.

600 cubic feet of air, under the mean temperature and pressure, weigh a little more than 45 pounds avoirdupois; they contain 10·4 pounds of oxygen, which would burn very nearly 4 pounds of carbon, and disengage 16,000 times as much heat as would raise by one degree per cent. the temperature of two pounds of water. These 16,000 portions of heat, produced every minute, will replace 16,000 other portions of heat, dissipated by the sides of the furnace, and employed in heating the gases which escape from its mouth. This must take place in order to establish the assumed equilibrium of caloric.

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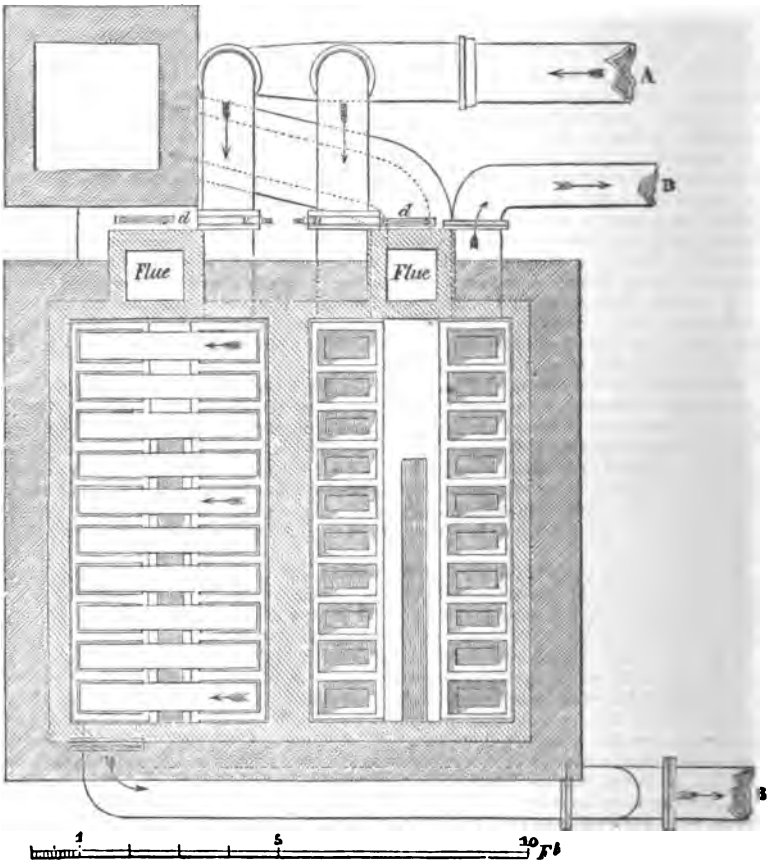
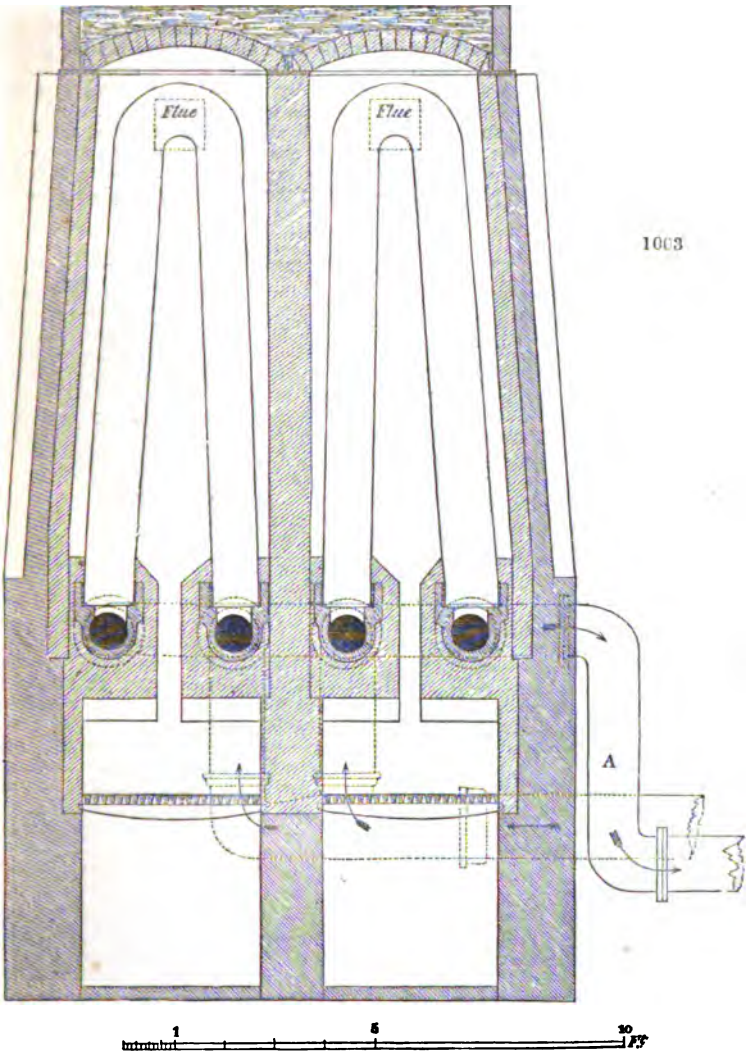


If the 45 pounds of air be heated beforehand up to 300° C., they will contain about the eighth part of the heat of the 16,000 disengaged by the combustion, and there will be therefore in the same space one-eighth of heat more, which

will be ready to operate upon any bodies within its range, and to heat them one-eighth more. Thus the blast of 300° C. gives a temperature which is nine-eighths of the blast at zero C., or at even the ordinary atmospheric temperature; and as we may reckon at from 2,200° to 2,700° F. (from 1,200° to 1,500° C.), the temperature of blast furnaces worked in the common way, we perceive that the hot-air blast produces an increase of temperature equal to from 270° to 360° F.

Now in order to appreciate the immense effects which this excess of temperature may produce in metallurgic operations, we must consider that often only a few degrees more temperature are required to modify the state of a fusible body, or to determine the play of affinities dormant at lower degrees of heat. Water is solid at 1° under 32° F.; it is liquid at 1° above. Every fusible body has a determinate melting point, a very few degrees above which it is quite fluid, though it may



be partly below it. The same observation applies to ordinary chemical affinities. Charcoal, for example, which reduces the greater part of metallic oxides, begins to do so only at a determinate pitch of temperature, under which it is inoperative, but a

few degrees above, it is in general lively and complete. It is unnecessary in this article to enter into any more details, to show the influence of a few degrees of heat more or less in a furnace upon chemical operations, or merely upon physical changes of state.

Figs. 1002, 1003, exhibit the apparatus of the hot blast as mounted at the Colner Park works, belonging to William Jessop, Esq., in every requisite detail. The drawings from which the wood-cuts are faithfully copied were kindly furnished for this work by Mr. Joseph Glyn, F.R.S., the distinguished engineer of the Butterly Iron Works.

The smelting furnaces have now generally three tuyères, and three sets of air heating furnaces. The figures show two sets built together; the third set being detached on account of peculiar local circumstances. The air enters the horizontal pipe A, in the ground plan, *fig.* 1002, on one side of the arched or syphon pipes, shown in upright section in *fig.* 1003, and passes through these pipes to the horizontal pipe, B, on the other side; whence it proceeds to the blast furnace. These syphon pipes are flattened laterally, their section being a parallelogram, to give more heating surface, and also more depth of pipe (in the vertical plane), so as to make it stronger, and less liable to bend by its own weight when softened by the red heat. This system of arched pipe apparatus is set in a kind of oven, from which the flue is taken out at the top of it; but it thence again descends, before it reaches the chimney, entering it nearly at the level of the fire grate, (as with coal gas retorts). By this contrivance, the pipes are kept in a bath of ignited air, and not exposed to the corroding influence of a current of flame. The places and directions of these oven flues are plainly marked in the drawing.

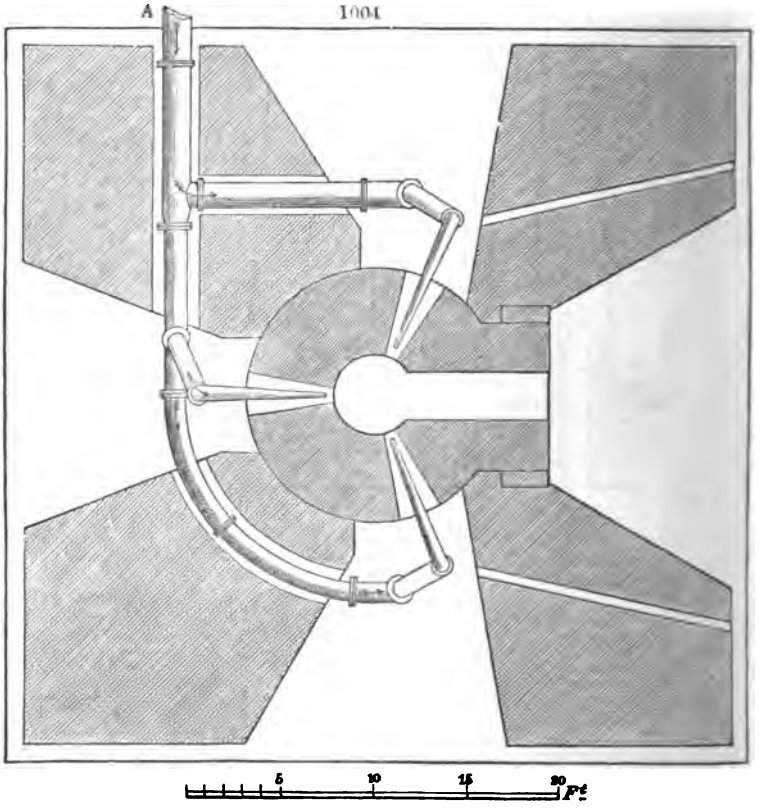


Fig. 1004 is a plan of the blast furnace, drawn to a smaller scale than that of the preceding figures.

The three sets of hot-blast apparatus all communicate with one line of conducting

pipes, A, which leads to the furnace. Thus in case of repairs being required in one set, the other two may be kept in full activity, capable of supplying abundance of hot air to the blast, though of a somewhat lower temperature. See SMELTING for constructions of different blast furnaces; also PUDDLING.

During a visit which Dr. Ure made to Mr. Jessop, at Butterly, he found this eminent and very ingenious iron-master had made several improvements upon his hot-blast arrangements, whereby he prevented the alteration of form to which the arched pipes were subject at a high temperature, as also that he was about to employ five tuyères instead of three. For a drawing and explanation of his furnace-feeding apparatus, see SMELTING.

The experiments through which Mr. Nielson's important discovery was introduced into the iron manufacture, were made at the Clyde Iron Works, where the fuel generally made use of was coke, derived from splint coal; during its conversion into coke, this coal sustained a loss of 55 per cent. During the first six months of the year 1829, when all the cast iron in the Clyde Iron Works was made by means of the cold blast, a single ton of cast iron required for fuel to reduce it 8 tons 1¼ cwt. of coal, converted into coke. During the first six months of the following year, while the air was heated to near 300° F., 1 ton of cast iron required 5 tons 3¼ cwt. of coal converted into coke. The saving amounts to 2 tons 18 cwt. per ton of iron, from which must be deducted the coal used in heating the air, which was nearly 8 cwt. This great success induced the Scotch iron-masters to try a higher temperature, and to substitute raw coal for coke; and during the first six months of the year 1833, the blast being heated to 600°, 1 ton of cast iron was made with 2 tons 5¼ cwt. of coal. Add to this 8 cwt. of coal for heating, and we have 2 tons 13¼ cwt. of coal to make one ton of iron. An extraordinary impetus was given by this discovery to the iron manufacture in Scotland, where, from the peculiar nature of the coal, and from the circumstance that, with a heated blast, Mushet's blackband ironstone could be exclusively used, its importance was more highly felt than in England and Wales. According to Mr. Finch's statement (Scrivenor's "History of the Iron Trade"), there were in 1830 only eight works in operation in Scotland, which made in that year 37,500 tons of pig iron; in 1838 there were eleven works, consisting of 41 furnaces, which made 147,500 tons, being an increase in eight years of 110,000 tons per annum; in 1839 there were 50 furnaces in blast, making 195,000 tons; in 1851, 750,000 tons of pig iron were made; and in 1856, with 127 furnaces in blast, the make rose to 880,500 tons. The influence of hot blast has likewise been felt in the anthracite district of South Wales, where that coal is now successfully used, and where several new furnaces have in consequence been erected. In short, notwithstanding the opposition with which the introduction of hot blast was met by engineers, as being destructive of the quality of the iron, so great have been the advantages derived from it, that at the present time more than nineteen-twentieths of the entire produce of the kingdom is made in furnaces blown with heated air.

Mr. Truran, in his recent work on the iron manufacture of Great Britain, gives it as his opinion that the effects of hot blast have been greatly exaggerated, and that it is to improvements in the preparation of fuel and ore in the furnaces, in blowing engines, and in the smelting process, far more than to the heating of the blast, that we must refer the great reduction in the yields of coal in recent times; he thinks that the comparatively large produce which has been obtained from the Scotch furnaces, is to be referred to the general use of carbonaceous ore, which melts at a low temperature; and which, from its comparative freedom from earthy matters, requires but a minimum dose of limestone for fluxing. Against this opinion of an English writer on iron smelting we may place that recorded by an American metallurgist, Mr. Overman, who has written a large and in many respects a valuable treatise on the manufacture of iron, as conducted in America. "The economical advantages arising from the application of hot blast, casting aside those cases in which cold blast will not work at all, are immense. The amount of fuel saved in anthracite and coke furnaces varies from 30 to 60 per cent. In addition to this, hot blast enables us to obtain nearly twice the quantity of iron within a given time that we should realise by cold blast. These advantages are far more striking with respect to anthracite coal than in relation to coke or to bituminous coal. By using hard charcoal, we can save 20 per cent. of fuel, and augment the product 50 per cent. From soft charcoal we shall derive but little benefit, at least where it is necessary to take the quality of the iron into consideration."

The following tables, embodying the general results of an extended series of experiments on the relative strength and other mechanical properties of cast iron, obtained by the hot and cold blasts, are extracted from a report presented to the British Association (1837) by Messrs. Eaton, Hodgkinson, and William Fairbairn.

Of the three columns of numbers, the first represents the strength or other quality

in the *cold* blast iron, the second that in the *hot*, the third is the ratio of these qualities; the figures included in parentheses indicate the number of experiments from which the results have been deduced.

	Cold Blast.	Hot Blast.	Ratio, representing Cold Blast by 1000.
Carron Iron, No. 2.			
Tensile strength in lbs. per square inch	16,583 (2)	13,506 (3)	1000 : 809
Compressive strength in lbs. per inch, from castings torn asunder	106,375 (3)	108,540 (2)	1000 : 1020
Ditto, from prisms of various forms	100,631 (4)	100,738 (2)	1000 : 1001
Ditto, from cylinders	125,408 (13)	121,685 (13)	1000 : 970
Transverse strength from all experiments	- - (11)	- - (13)	1000 : 991
Power to resist impact	- - (9)	- - (9)	1000 : 1005
Transverse strength of bars one inch square in lbs.	476 (3)	463 (3)	1000 : 973
Ultimate deflection of do. in inches	1·313 (3)	1·287 (3)	1000 : 1018
Modulus of elasticity in lbs. per square inch	17,279,500 (2)	16,085,000 (2)	1000 : 931
Specific gravity	7,066	7,046	1000 : 997
Devon Iron, No. 3.			
Tensile strength	- - -	21,907 (1)	
Compressive strength	- - -	145,435 (4)	
Transverse do. from experiments generally	- - (5)	- - (6)	1000 : 1417
Power to resist impact	- - (4)	- - (4)	1000 : 2786
Transverse strength of bars one inch square	448 (2)	537 (2)	1000 : 1199
Ultimate deflection do.	·79 (2)	1·09 (2)	1000 : 1380
Modulus of elasticity	22,907,700 (2)	22,473,650 (2)	1000 : 981
Specific gravity	7,295 (4)	7,229 (2)	1000 : 991
Cold Talon Iron, No. 2.			
Tensile strength	18,855 (2)	16,676 (2)	1000 : 884
Compressive strength	81,770 (4)	82,739 (4)	1000 : 1012
Specific gravity	6,955 (4)	6,968 (4)	1000 : 1002
Carron Iron, No. 3.			
Tensile strength	14,200 (2)	17,755 (2)	1000 : 1250
Compressive strength	115,542 (4)	133,440 (3)	1000 : 1156
Specific gravity	7,135 (1)	7,056 (1)	1000 : 989
Buffery Iron, No. 1.			
Tensile strength	17,466 (1)	13,434 (1)	1000 : 769
Compressive strength	93,366 (4)	86,397 (4)	1000 : 925
Transverse strength	- - (5)	- - (5)	1000 : 931
Power to resist impact	- - (2)	- - (2)	1000 : 963
Transverse strength of bars one inch square	463 (3)	436 (3)	1000 : 942
Ultimate deflection do.	1·55 (3)	1·64 (3)	1000 : 1058
Modulus of elasticity	15,381,200 (2)	13,730,500 (2)	1000 : 893
Specific gravity	7,079	6,958	1000 : 983

mean 917

These results contain nearly the whole of the information afforded by the investigation. From the numbers in the tables, it will be seen that in Buffery iron No. 1 cold blast somewhat surpasses hot blast in all the following particulars.—1, direct tensile strength; 2, compressive strength; 3, transverse strength; 4, power to resist impact; 5, modulus of elasticity or stiffness; 6, specific gravity; while the only numerical advantage possessed by the hot blast metal is that it bends a little more than the cold before it breaks. In No. 2 the advantages of the rival kinds are more nearly balanced, still rather in favour of the cold blast. No. 3 hot blast Carron iron resists both tension and compression better than cold blast of the same denomination; and No. 3 hot blast from the Devon works in Scotland is remarkably strong, while No. 3 cold blast is comparatively weak, notwithstanding its high specific gravity. On the whole it would appear from the experiments, that while the irons of No. 1 have been somewhat deteriorated in quality by the hot blast, those of No. 3 have been benefited by its mollifying powers; while those of No. 2 have been but very slightly affected; and from the evidence brought forward, it is rendered highly probable that the introduction of a heated blast, whilst it has, perhaps, to a certain extent, injured the softer irons, has improved those of a harder nature; and considering the small deterioration that the irons of the quality No. 2 have sustained, and the apparent benefit of those of No. 3, together with the saving effected by the heated blast, there seems good reason for the process becoming so general as it has done.

The following *general* summary of results, as derived from the experiments of Messrs. Hodgkinson and Fairbairn on the transverse strength of hot and cold blast iron exhibits at one view the ultimatum of the whole investigation.

	Ratio of Strength: that of Cold Blast being represented by 1000.	Ratio of Powers to sustain Impact: Cold Blast being 1000.
These irons are from Mr. Hodgkinson's experiments: —		
Carron iron, No. 2	1000 : 990·9	1000 : 1005·1
Devon iron, No. 3	1000 : 1416·9	1000 : 2785·6
Buffrey iron, No. 1.	1000 : 930·7	1000 : 962·1
These irons are from Mr. Fairbairn's experiments: —		
Coed Talon iron, No. 2	1000 : 1007	1000 : 1234
Coed Talon ditto, No. 3	1000 : 927	1000 : 925
Elsicar and Milton, ditto	1000 : 818	1000 : 875
Carron ditto, No. 3	1000 : 1181	1000 : 1201
Muirkirk, No. 1	1000 : 927	1000 : 823
Mean	1000 : 1024·8	1000 : 1226·3

Dr. Thompson's chemical examination of several samples of hot and cold blast iron is appended to this report. According to the experiments of this distinguished chemist, iron smelted by *hot* blast contains a greater proportion of iron, and a smaller proportion of silicon, carbon, and aluminum, than when smelted by cold air. The mean specific gravity of 8 specimens of Scotch cold blast iron No. 1 was 6·7034; the mean of 5 specimens of hot blast from the Carron and Clyde iron works was 7·0623, so that the density of cold blast iron is less than that of hot. The mean of 6 analyses of cold blast iron No. 1 gave 3½ atoms of iron, 1 atom of carbon, silicon, and aluminum; the proportion of these three constituents being very nearly 4 atoms of carbon, 1 atom of silicon, and 1 atom of aluminum, consequently Scotch cold blast iron consists of 20 atoms of iron (with a little manganese), 4 atoms of carbon, 1 atom of silicon, and 1 atom of aluminum. The mean of 5 analyses of hot blast iron No. 1, gave 6½ atoms of iron and manganese to 1 atom of carbon, silicon and aluminum, from which it would appear that cast iron smelted with a heat blast is *purer* than when the blast is cold. This however, is not the case, as the numerous analyses of both varieties that have been made during the last few years concur in proving. Hot blast grey iron smelted with mineral coal contains a much higher percentage of silicon than the same variety of cast iron smelted from the same ores by cold blast; in other respects, provided the process of reduction is complete, *i. e.* when little or no iron passes off with the slag, there is very little chemical difference between the two varieties, as will be seen in the following table, which contains the results of a series of analyses of hot and cold blast iron, which we have lately had occasion to make, under circumstances peculiarly favourable for instituting the comparison, the furnaces working with the same ores, and making the same class of iron, viz. good No. 3 grey pig.

Analyses of Cast Iron No. 3, *smelted by Hot Blast.* (Dr. Noad.)

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	Mean.
Silicon	2·500	3·140	3·380	2·440	3·200	3·190	3·120	2·260	2·900
Graphite	3·520	3·100	3·210	3·102	3·340	3·320	3·340	3·294	3·290
Sulphur	0·045	0·090	0·079	0·069	0·072	0·046	0·072	0·054	0·067
Phosphorus	0·318	0.422	0·308	0·394	0·422	0·480	0·820	0·374	0·379
Metallic iron per cent.								93·15	

Analyses of Cast Iron No. 3, *smelted by Cold Blast.* (Dr. Noad.)

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	Mean.
Silicon	1·050	1·400	1·029	0·940	1·372	1·498	1·466	1·400	1·268
Graphite	3·370	3·184	3·270	3·140	3·333	3·274	3·242	3·197	3·251
Sulphur	0·024	0·037	0.045	traces	0·029	0·037	0·028	0·024	0·028
Phosphorus	0·210	0·314	0·387	0·361	0·372	0·372	0·342	0·354	0·339
Metallic iron per cent.								96·0	

The true reason of the frequent inferiority of hot blast iron has been correctly given by Mr. Blackwell. Furnaces blown with heated air exert greater reductive power

than those in which a cold blast is used. This has led, since the introduction of hot blast, to the extensive use in iron smelting of refractory ores not formerly smelted, a large part of which have been ores of a class calculated to produce inferior iron, and it is to the use of ores of this nature, far more than from any deterioration in quality, arising from a heated blast, that this inferiority of hot blast iron is to be ascribed.

Utilisation of the waste gases given off from the furnace head. — The agent in the blast furnace by which the oxide of iron is reduced, is carbonic oxide, the presence of which therefore in great excess is indispensable to the operation of the furnace. The flames rising from the tunnel head, which make a blast furnace at night such an imposing object, are occasioned principally by the combustion of this gas, on coming into contact with the oxygen of the atmosphere; the attention of practical men was first called to the enormous waste of heat which this useless flame entailed by Messrs. Bunsen and Playfair, and the application of the gas to a useful purpose may be ranked next to that of the heated blast, as the most important of the recent improvements in the iron manufacture. The gases evolved from iron furnaces where coal is used as the fuel, contain the following constituents, viz. *nitrogen, ammonia, carbonic acid, carbonic oxide, light carburetted hydrogen, olefiant gas, carburetted hydrogen of unknown composition, hydrogen, sulphuretted hydrogen*, and *aqueous vapour*. The nature of the combustible gas stands in a relation so intimate to the changes suffered by the materials put into the furnace, that its different composition in the various regions of the furnace indicates the changes suffered by the materials introduced as they descend in their way to the entrance of the blast. Now as the examination of this column of air in its various heights in the furnace must be the key to the questions upon which the theory and practice of the manufacture of iron depend, it was of the first importance to subject it to a rigid examination; this accordingly has been done by the above named eminent chemists, and subsequently by Ebelmen. We shall return to a consideration of the results they obtained presently, confining our attention at present to the composition of the gases at the mouth of the furnace, and to the methods which have been adopted to utilise them.

In order to arrive at a knowledge of the composition of these gases, M. Bunsen first studied minutely the phenomena which would ensue were the furnace filled with fuel only: by a careful distillation of a known weight of coal, and analysing of the products, he obtained results embodied in the subjoined table: —

Carbon	68·925
Tar	12·230
Water	7·569
Light carburetted hydrogen	7·021
Carbonic oxide	1·135
Carbonic acid	1·073
Condensed hydrocarbon and olefiant gas	0·753
Sulphuretted hydrogen	0·549
Hydrogen	0·499
Ammonia	0·211
Nitrogen	0·035
	100·000

Now, in the furnace, the oxygen introduced by the blast is consumed in the immediate vicinity of the tuyère, being there converted into carbonic oxide, and the coal loses all its gaseous products of distillation much above the point at which its combustion commences, near in fact, the top of the furnace; the fuel with which the blast comes into contact is therefore coke, and upon calculating the amount of carbonic oxide produced by the combustion of 68·925 per cent. of carbon, and the nitrogen of the air expended in the combustion, we get as the composition by volume of the gases escaping from a furnace filled with Gasforth coal the following: —

Nitrogen	62·423
Carbonic oxide	33·163
Light carburetted hydrogen	2·527
Carbonic acid	0·139
Condensed hydrocarbon	0·151
Sulphuretted hydrogen	0·091
Hydrogen	1·431
Ammonia	0·070
	100·000

With this preliminary information, Bunsen proceeded to calculate the modification of the gaseous mixture occasioned by the introduction into the furnace of iron ore and limestone. The materials used for the production of 140 lbs. of pig-iron were:—420 lbs. calcined iron ore; 390 lbs. coal; 170 lbs. limestone. From 100 parts of the coal, 67·228 parts of coke were obtained; but from this must be deducted 2·68 ashes, and 1·18 carbon entering into combination with the iron; which leaves as the quantity of carbon actually burnt into carbonic oxide before the tuyère 63·368; part of this carbonic oxide undergoes oxidation into carbonic acid at the expense of the oxygen in the oxide of iron which it reduces; a further quantity of carbonic acid is derived from the limestone; so that the gases returned to the mouth of the furnace by the combustion of the 67·228 parts of coke, the reduction of the corresponding quantity of ore, and the decomposition of limestone, consist of—

Nitrogen	282·860
Carbonic acid	59·482
Carbonic oxide	121·906
	464·248

Add to this the products of the distillation of the coal, and we get the following as the per-centage compositions by weight and measure of the gases issuing from the mouth of the furnace.

	By weight.	By volume.
Nitrogen	59·559	60·907
Carbonic acid	12·765	8·370
Carbonic oxide	26·006	26·846
Light carburetted hydrogen	1·397	2·536
Hydrogen	0·078	1·126
Condensed hydrocarbon	0·108	0·112
Sulphuretted hydrogen	0·053	0·045
Ammonia	0·054	0·058
	100·000	100·000

The calculations of the quantity of heat capable of being realised in the furnace by the combustion of the furnace gases are founded on the data on the heat of combustion given in the posthumous papers of Dulong, according to which—

1 kilogramme or 15,444 grains of

Carbon burning to CO, heats 15,444 grains of water to	1499°C
" CO^2	7371°
Carbonic oxide	2502°
Hydrogen	34706°
Light carburetted hydrogen	13469°
Olefiant gas	12322°
Sulphuretted hydrogen	4476°
Ammonia	6060°

Using these numbers it is found that by the combustion of 100 of the furnace gases there are generated from the

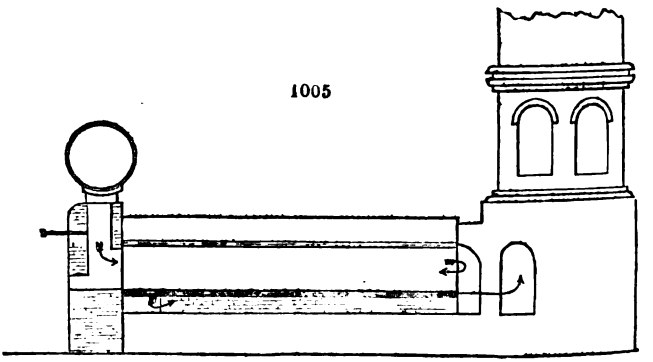
59·559	nitrogen	0000
12·765	carbonic acid	0000
26·006	carbonic oxide	65067
1·397	carburetted hydrogen	18826
0·078	hydrogen	2704
0·108	olefiant gas	1331
0·053	sulphuretted hydrogen	238
0·034	ammonia	208
		88374 =

units of heat *generated*, the *unit* being understood to mean the amount of heat necessary to raise 1 kilogramme = 2·204 lbs. = 15444 grains of water from 0° centigrade, to 1° cent. The amount of heat *realized* in the furnace is limited to that produced by the expenditure of the oxygen, corresponding to 59·559 nitrogen in the production of carbonic oxide; this amounts to 20001 units: hence follows the remarkable conclusion, that in the furnace which was the subject of experiment, not less than 81·54 per cent.

of the fuel is lost in the form of combustible matter still fit for use, and that only 18·46 per cent. of the whole fuel is realised in carrying out the processes in the furnace.

The temperature which should be produced by the flame of the furnace gases when burnt with air, is found by dividing the units of heat, viz. 883·74 arising from the combustion of 1 kilogramme of the gases by the number resulting when the quantity of the products of combustion is multiplied by their specific heat (1·9338 × 0·2696): we thus get the number 3083°F.; but this is below the truth, inasmuch as there is an accession of combustible gases at the mouth of the furnace, arising from the decomposition of the liquid products of the distillation of the coal in its passage over the red hot fuel. Making proper correction for this, and using numbers derived from actual experiments, Messrs. Bunsen and Playfair calculated the temperature of the gases when generated under favourable conditions at 3214° F., and even this may be increased to 3632° F., a temperature far above that of cast iron, by the using a blast sufficiently heated. In utilising these waste gases, care must be taken not to remove them from the furnace till they really are *waste*, that is, until they have done their work in the furnace; it is obvious that no combustible matter could be removed from the lower regions of the furnace without seriously deranging the operations essential to the reduction and smelting of the ore. In order to remove the gases effectually, and without injury to the working of the furnace, and in such a state as will permit their combustion to be effected with most advantage, the height of the furnace must be raised, the full width of the mouth being retained, and the gases must be withdrawn sufficiently far below the mouth for them to be obtained dry, and also beneath the point where they begin to enter into combustion from contact with the atmospheric air.

1005



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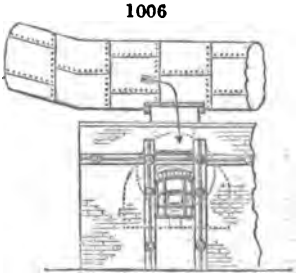

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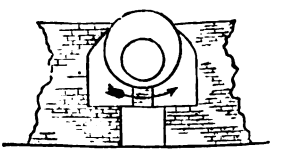
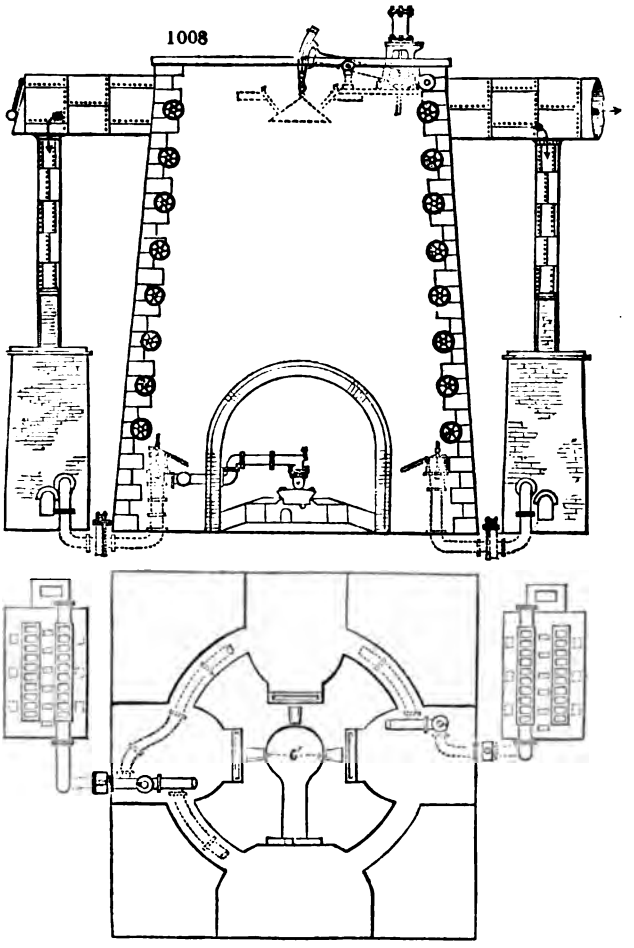


Various modes of collecting the gases have been tried; the best seems to be that adopted at Ebbw Vale, Sirhowy, and Cwm Celyn. A funnel-shaped casting, equal in its largest diameter to the throat of the furnace, projects into the interior a depth of 4 or 5 feet; the orifice at the bottom, from 3 to 5 feet in diameter, is closed by a conical casting, the apex upwards, from which a chain proceeds to a lever having a counterpoise at the other end. (See *fig.* 1000.) The materials are filled into the funnel-shaped receptacle, and are charged into the furnace with a uniform distribution, by lowering the cone by means of suitable machinery, which again returns it to its place when emptied. The circular space around the funnel, inside the furnace, forms a chamber

for the reception of the gases, from which they are conveyed by brick tunnels or iron piping to the place of combustion. The whole arrangement will be clearly understood



by an inspection of the accompanying plans, *Figs.* 1005, 1006, 1007, 1008, 1009, kindly furnished to the writer by the proprietor of the Cwm Celyn and Blaina Iron Works.

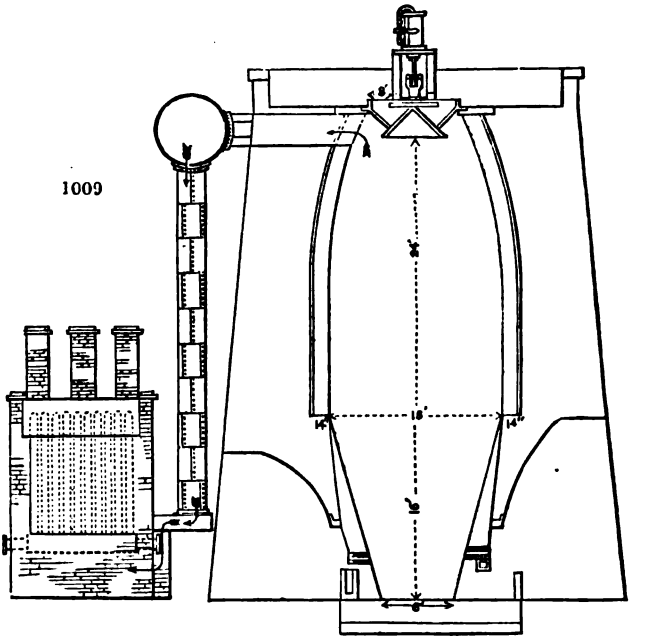
Fig. 1007 shows the plan of extracting the gases which is adopted at the Brymbo Iron Works, near Wrexham, the same being the patent of C. E. Darby.

It consists of a large pipe or tube inserted into the middle of the top part of the furnace, which descends a short distance down into the materials, and is carried over the top of the side of the furnace in the form of a syphon, a continuation of which pipe is taken to the boilers, or hot air stoves, where the gas is burned in the usual way. The principal advantage claimed by this method, is that it puts no check on the free escape of the gases, by which the driving of the furnace is impeded, and the quality of the iron deteriorated. The patentee estimates the saving of fuel with two furnaces making 240 tons of iron per week, by applying the gas to the blast engine boilers and hot air stoves, at 1200*l.* a year. Thus :—Consumption of fuel at engine and stoves equal to 7 cwts. of good coal per ton of iron, made at 3½ per cwt., is 2*s.* 0½*d.*, say 2*s.* per ton on 12,480 tons, or 1248*l.*

The causes of derangement in the working of blast furnaces when the gases are drawn off to be utilised elsewhere, have been diligently studied by Mr. George Parry, of Ebbw Vale ; and he has kindly furnished us with the following resumé of his observations, for insertion in this article.

The manner in which the waste gases were formerly collected, was by sinking an iron tube, 7 feet deep, into the throat of the furnace, the diameter of the tube being

1009



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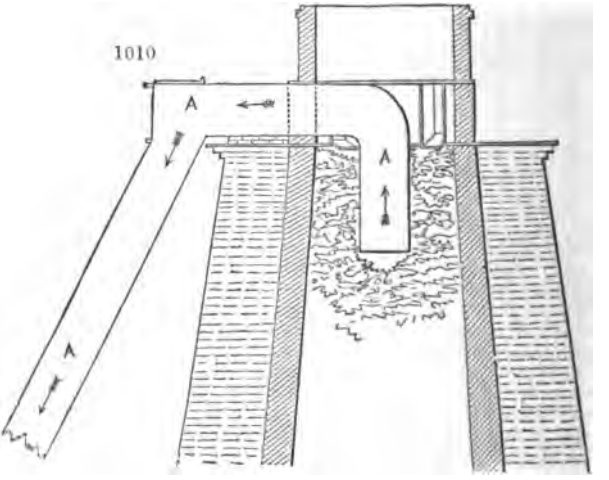


about 3 feet less than that of the throat, thus leaving an annular space of 18 inches between the walls of the furnace and the sides of the tube. From this space the gases were allowed to pass off by the pressure within the furnace, through a pipe which penetrated the ring and walls. When the tube was kept full of minerals, about

⅓ or ¼ only of the gas escaped into the open air, the rest passing into the annular chamber; and when this state of things was continued, those troublesome adhesions of masses of semifused materials above and around the boshes, technically termed "scaffolds," occurred, with the usual accompaniments of black cinder and inferior iron. It is evident that when the tube was kept full of minerals, the contents acted as a loose stopper to the current of hot gases forced up by pressure from beneath, and diverted them towards the annular space where there was no such resistance, thus leaving the minerals in the central parts of the furnace insufficiently supplied with the upward current, and consequently with heat; the minerals, on the other hand, surrounding this cold central cone, were supplied with more than their usual quantity of heat, as was evidenced by the burning of tuyères, and by the destruction of the brickwork in their neighbourhood. In this state of things, the ores in the external portions of the furnace would become reduced and converted into grey metal; while those in the central portion would, according to the degree of deviation of the ascending current of heated gases from them, descend to the point of fusion either thoroughly deoxidised, and slightly carbonised, or possibly with a portion still in the state of oxide, and mixing there with the properly reduced ores, enter into fusion with them, producing a mixture of irons which must necessarily prove of inferior quality, and a black cinder from the unreduced oxides. When the iron tube in the throat of the furnace was kept only partially filled with minerals, much more gas escaped into the open air, as might have been expected, and consequently more traversed the central parts of the furnace; and it was always observed that when that mode of filling was adopted, the furnace worked much better: but then the object, viz. that of economising the gases, was not attained. Differently formed furnaces were found to be disturbed in different degrees by this system of drawing off the gases: the old conical *narrow* topped furnaces were affected very much less than the improved modern *domed* top furnace of large capacity, from which all attempts to take off any useful portion of the gases proved absolute ruin. It might be argued, that as the same quantity of blast and fuel were used as heretofore, the ascending current of heated gases ought to produce the same deoxidising and carbonising effect on the superincumbent mass, whatever direction they might take in making their escape at the upper region of the furnace; for if the central part should not have been sufficiently acted upon, the external annulus would have more than its usual share of chemical influences. But when it is considered that iron is only capable of taking up a certain quantity of carbon, and no more, it follows that after having received this dose, its further exposure in the external parts of the furnace where the heated gases abound can do nothing towards supplying the deficiency of carbon in the metal reduced in the central part. From these considerations it became evident, that no system of drawing off the gases around the sides, whether by the insertion of an iron tube into the throat, or by lateral openings through the walls into a chamber surrounding the top of the furnace, can be adopted without more or less injury to its action; and that the only unobjectionable mode would be to take the gases from a chamber above the surface of the minerals, thus equalising the pressure on the whole sectional area of the mouth, and thereby allowing an equally free flow for the ascending current up the middle, as well as up the sides of the furnace. By this method the whole of the waste gases would become utilised, instead of a portion only, and the furnace would be restored to its original state, inasmuch as the direction of the flow of heated gases would not be interfered with by unequal resistance. To form this chamber, the furnace must be covered in, and fed through a hopper, a plan long adopted at the Codner Park Iron Works, with the supposed advantage of scattering the minerals around the sides of the furnace, and preventing their accumulating in the centre; a conical charger of this description, but fixed in the throat of the blast furnace, was in use at the Cyfartha Works more than half a century ago, the minerals being thrown by baskets to the centre of the cone, and allowed to roll down to the sides of the furnace, thus giving a cup form to the surface of the minerals, the larger lumps of course rolling to the centre, and affording a freer passage in that direction for the upward current. It was not, however, until January, 1851, that a trial was made, at the Ebbw Vale Works, of an apparatus of this description for collecting the gases. It was then supplied to one of the old forms of conical furnace with a narrow top, and the trial proved eminently successful, the furnace producing any quantity of iron required according to the burden, as usual. Several other furnaces were similarly furnished in and around the neighbourhood, and it was now thought that the principle of taking off the gases from a chamber above the surface of the minerals, together with the conical mode of charging, were the only indispensable conditions to success for all furnaces; and some even which were originally built too narrow at the mouth, were actually improved by the new method of charging, which did not allow of the sur-

faces of the minerals rising higher than about 6 feet from the top; thus giving to the furnace a diminished height, and as a consequence of its conical shape a wider mouth. Further experience, however, demonstrated the fallacy of this general conclusion.

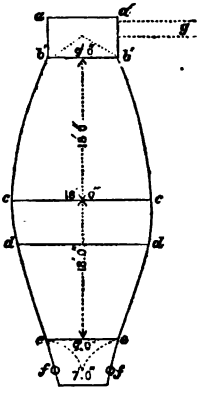
A large domed furnace was furnished with the same kind of charging apparatus which proved so successful in former instances, but to the astonishment of all it turned out a complete failure, the same derangements occurring as in the former cases, where a portion of the gases only was collected, by sinking a tube into the throat. Now this furnace could not be filled to within 6 or 7 feet of the top, and at that depth the diameter was 13 ft. 6 in., owing to the sharp sweep of the dome; the actual working furnace was therefore 37 feet high, instead of 44 feet, with a mouth 13 ft. 6 in., instead of 8 ft.; and as the minerals cannot lie so close against the smooth sides of the walls as they do locked in each other in the more central region of the furnace, a much freer discharge of the gases up the sides must take place; and on boring a hole through the side of the furnace, in the neighbourhood of the boshes, it was found that 2 feet in, the coke and other minerals were at a white heat, but a little further on towards the centre, lumps of black blazing coal were found, with ironstone which had not even attained a red heat. The charging apparatus was now raised with the furnace 5 feet, and the minerals drawn up an inclined plane to the charging cup, thus enabling it to be kept full to within a short distance of the old mouth, after which the furnace worked as usual. That diminished height was not the cause of the bad working of the furnace was afterwards proved, the furnace having been blown out for repairs, and re-lined with brickwork, giving it that form and proportion deemed necessary, from the experience gained; the height being now only 37 feet instead of 44, and the diameter of the mouth 7 ft. 6 in., or one half of that at the boshes. The same charging apparatus which failed before, mounted 6 feet above the mouth, was used, and the furnace has now been working uninterruptedly for 5 years, turning out as much as 160 tons of grey pig iron per week, or when burdened for white iron, 200 tons; economising the whole of its gas, and as much under the control of the manager as any furnace, either closed top or open top, can reasonably be expected to be. It is clear, therefore, that the covering of the top has nothing whatever to do with the action of a furnace kept full to the mouth, and having the proper form and proportions from that point downwards. The mouth must be understood to be that part of the furnace which represents the mean height of the surface of the minerals, and not the top of the masonry, and the question arises, what proportion should that bear in diameter to the boshes or widest part, and what the latter should be with reference to height in order to secure a maximum economical effect on the quality of the iron made, and on the yield of fuel. This state of perfection can exist only when the *isothermal* lines in the furnace are parallel to the horizon. The temperature of the minerals at any given height above the tuyères being the same through the whole horizontal sectional area at that height, and consequently arriving at the zone of fusion in an equally prepared state. If the mouth of the furnace be too wide, the heated gases have a greater tendency to pass up the sides than through the centre, thus destroying the horizontality of the lines of equal temperature, and giving them a curved form with the *convex* side downwards; hence ores at different temperatures, and of various stages of preparation, will occupy any given horizontal sectional area of the furnace; these descending together and mixing in the zone of fusion, will produce evils in proportion to the extent of the deflection of the curves from a horizontal line. On the contrary, if the mouth of the furnace be too narrow in proportion to the other parts, we may expect an undue portion of the gases to pass up the centre, leaving the minerals around the sides comparatively unacted upon. It is easy to see that evils of the same kind as before must exist here, the isothermal lines becoming now *concave* downwards, instead of *convex*, giving as before, through any horizontal section of the furnace, ores at various temperatures, and at different degrees of deoxidation or carburation, according to the depth which they may have attained in the furnace. There are several instances of furnaces originally built with too narrow tops, being greatly improved by widening them; this may conveniently be done by feeding them through a conical charger, which by lowering the surface of the minerals *virtually* increases the width of the mouth: on the other hand, furnaces having the opposite defect of being too wide at the top, may be benefitted to some extent, provided the walls are nearly perpendicular, or do not widen too rapidly downwards, by employing as large a cone as it is possible to work in the throat; for by the use of this feeder, the minerals must fall close to the sides, and the larger lumps roll to the axis of the furnace, and so facilitate the passage of the gases in that direction, besides giving to the surface a concave or cup form, and consequently a diminished height and resistance to the upward current in the middle. This principle of improving the

charging of such defective furnaces is even carried out to some extent in feeding open top furnaces where the gases are wasted. The charging plate is so placed as to prevent the nose of the barrow from projecting any distance into the furnace; the minerals being thus discharged close to the edge, the larger lumps have a tendency to roll over towards the centre, leaving the smaller at the ring walls, to check the upward current in that direction.

The above considerations will materially assist in furnishing an answer to the oft repeated and very important question, "What form and proportions should a blast furnace have to produce the best results in quality of iron, and in economy of fuel, whether worked on the open top principle, or enclosed for the purpose of utilising the waste gases?" Experience has proved that when the mouth of the furnace is one half the diameter of the widest part, good work is obtained, and that any deviation from that proprortion, if in excess, has been productive of great derangement in its action. The height of the furnace should also bear a certain proportion to the greatest diameter, in order to secure an uniform flow of the ascending current through all its parts; for if the widest part bear too great a relation to the height, the boshes must necessarily be of a low angle, and consequently the minerals around the sides near their top be at too great a distance out of the direct line of passage of the ascending current, and consequently remain only partially prepared for fusion.

The proportions recommended by Mr. Parry, and which have been practically tested most satisfactorily in several instances, are as shown in *fig.* 1011. The mouth *b' b'* one half the diameter of the widest part *c c*, and this should not be at a less depth than its own diameter. The sides of the furnace to this depth should be formed slightly dome-fashioned, for the purpose of giving to that region a larger capacity than would be obtained by a conical form. The radius of the curve should be at right angles to the axis of the furnace, and formed by a prolongation of the line representing the greatest diameter. When the radius is set at a great angle with this line, which is often done to give greater capacity to the domed part, the distortion produced by the sharpness of the curve may leave a segment of the minerals unacted upon by the gases in their passage to the mouth, and entail greater evils than would be compensated for by incre sed capacity. The curve is continued below the widest part of the furnace till it meets the top of the boshes *d d*, the angle of which should not be less than 70°, and start from the point of the tuyères *f f*. The depth also from the widest part to the tuyères should not be less than its own diameter *plus* half the diameter of the tuyères. These proportions give a blast furnace, of any determinate height fixed upon, the largest possible capacity it is capable of receiving, while remaining free from any distortion of form, likely to give a place for minerals to lie out of the way of the action of the upward gaseous current; when the height exceeds the proportion to its greatest diameter indicated in the figure, an unnecessary sacrifice in its capacity is the only loss entailed. The height above the mouth must be regulated by the kind of hopper used for charging, where it is intended to carry off the gases.

1011



Doubtless when the true principle of collecting these gases without injury to the blast furnace becomes more generally known, attention will be directed to the easiest and most convenient mode of introducing the minerals. The conical charger has only one disadvantage, that namely of allowing a great waste of gas during the charging; probably some kind of revolving hopper may be contrived to remedy this defect. It is of course assumed that the furnace is supplied with a proper quantity of blast, and of a density proportionable to the diameter across the tuyères, so as to maintain a vigorous combustion of the fuel to the very centre of the hearth, the top of which is indicated by the letters *e e*, for unless this is attained, a cold cone of minerals will remain in the centre, and produce derangements which no degree of perfection in the form of the furnace in the higher region can remove.

Theory of the blast furnace. — Analyses of the gases from a furnace at Alfreton in Derbyshire, at various depths below the surface, gave to Messrs. Bunsen and Playfair the results embodied in the subjoined table. The furnace was supplied with 80 charges in the course of 24 hours, each charge consisting of 390 lbs. of coal, 420 lbs. of calcined ironstone, and 170 lbs. of limestone, the product being 140 lbs. of pig iron. The gases were collected through a system of tubes of malleable iron, 1 inch in

diameter, and were received in glass tubes 4 inches long, and $\frac{3}{4}$ of an inch in diameter. The well known skill of M. Bunsen as a gas analyst is a guarantee of the accuracy of the determinations.

Composition of the Gases taken from different depths in the Furnace.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
	5 ft.	8 ft.	11 ft.	14 ft.	17 ft.	20 ft.	23 ft.	24 ft.	34 ft.
Nitrogen	55·35	54·77	53·57	50.·5	55·49	60·46	58·28	56·75	58·05
Carbonic acid	7·77	9·42	9·41	9·10	12·43	10·83	8·19	10·08	00·
Carbonic oxide	26·97	20·24	23·16	19·3	18·77	19·43	29·97	25·19	37·42
Light carburetted hydrogen	3·75	8·23	4·57	6·64	4·31	4·40	1·64	2·33	0·00
Hydrogen	6·73	6·49	9·33	12·42	7·62	4 83	4·92	5·65	3·18
Olefiant gas	0·43	0·85	0·95	1·57	1·38	0·00	0·00	0 00	0·00
Cyanogen	0·00	0·00	0·00	0·00	0·00	0·00	trace	trace	1·34

From these analyses it appears : —

1. That at a depth of 34 feet from the top, within 2 feet 9 inches of the tuyère, the gas was entirely free from carbonic acid, but contained an appreciable quantity of cyanogen.
2. That the nitrogen is at a minimum at 14 feet.
3. That carburetted hydrogen is found so low as 24 feet, indicating that at that depth, coal must be undergoing the process of coking.
4. That hydrogen and olefiant gases are at a maximum at 14 feet.
5. That the proportions between the carbonic acid and carbonic oxide are irregular, which is probably to be explained by the fact that water is decomposed as its vapour passes through the layers of hot coal.

The average composition of the gases evolved from the materials used in the blast furnace is somewhere between the two following numbers : —

Nitrogen	60·907	57·878
Carbonic acid	8·370	9·823
Carbonic oxide	26·846	24·042
Light carburetted hydrogen	2·536	2·743
Hydrogen	1·126	4·972
Olefiant gas	0·112	0·392
Sulphuretted hydrogen	0·045	0·035
Ammonia	0·058	0·115
	100·000	100·000

The proportion of nitrogen to oxygen as an average deduced from these analyses is 79·2 to 27. The product of the combustion of coal gives the same proportions as those existing in atmospheric air, viz. 79·2 : 20·08. The excess of oxygen must therefore depend upon the carbonic acid of the limestone, and the oxygen of the ore given to carbon during the process of reduction. Now, as at a depth of 24 feet the gas collected contained 27·6 and 26·5 oxygen to 79·2 nitrogen, it is held that at this depth the gas must already have accumulated all the oxygen of the ore, and the carbonic acid of the limestone; and the conclusion is drawn that in hot blast furnaces fed with coal, the reduction of the iron and the expulsion of the carbonic acid from the limestone takes place in the boshes of the furnace. The exact region of the furnace in which the melting of the iron and the formation of slag are effected is not exactly defined, but it is assumed that the point of fusion is at the top of the hearth. The region of reduction in a furnace smelting with coal must be much lower than when the fuel is coke or charcoal, because a large portion of the body of the furnace must be taken up in the process of coking, and the temperature is thereby so depressed, that it is sufficient neither for the reduction of the ore, nor for the expulsion of carbonic acid from the limestone.

The mean general results obtained by M. Ebelmen from a charcoal furnace at Clerval are given below. The methods of analysis adopted by this chemist were altogether different from those employed by Messrs. Bunsen and Playfair. For details we refer to his memoir in the *Annales des Mines*, vol. xix. p. 89, 1851.

No. of analysis -	I.	II.	III.		IV.	V.	VI.	VII.
Depth below mouth	3 ft. 3 in.	3 ft. 3 in.	9 ft. 9 in.	9 ft. 9 in.	19 ft. 6 in.	19 ft. 6 in.	27 ft.	Tymp.
Carbonic acid - -	12·01	11·95	4·14	4·23	0·49	0·07	0·00	0·93
Carbonic oxide -	24·65	22·85	31·56	31·34	35·05	35·47	37·55	39·86
Hydrogen - -	5·19	4·31	3·04	2·77	1·06	1·09	1·13	0·79
Carburetted hydrogen - - -	0·93	1·33	0·34	0·77	0·36	0·31	0·10	0·25
Nitrogen - -	57·22	58·56	60·92	60·89	63·04	63·06	61·22	58·17
Totals - -	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00
Oxygen, per 100 nitrogen - - -	42·5	40·8	32·7	32·7	28·5	28·2	30·7	35·8
Carbon vapour, per 100 nitrogen - -	32·8	31·7	29·6	29·6	28·5	28·5	30·7	35·9

I. Gas taken a short time after the introduction of the charge: II. the same taken a quarter of an hour after charging: III. gas collected through a cast-iron tube four inches in diameter; it rushed out with a noise and gave a sheet of flame, carrying with it particles of charcoal and dust: IV. gas collected by boring the masonry; it rushed out violently, burning with a blue coloured flame: V. the same taken an hour after: VI. gas collected by boring the masonry at the back of the furnace about 3½ feet above the tuyère; it burnt with a white flame, giving off fumes of oxide of zinc; it was collected through porcelain tubes: VII. gas collected through gun-barrels lined with porcelain; it was evolved with sufficient force to project scoriæ and even cast-iron.

The furnace was working with cold blast under a pressure of ·44 inch of mercury. The charges had the following composition: — Charcoal, 253 lbs.; minerals (various), 397 lbs.; limestone, 254 lbs. Thirty-two charges were driven in twenty-four hours; the furnace was stopped after every twenty charges; the produce being 3970 lbs. of black cast-iron; the daily yield being about 6175 lbs.

The experiments show that while the carbonic acid progressively diminishes downwards, the carbonic oxide progressively increases, the former altogether disappearing at a depth of 27 feet. On examining the numbers representing the oxygen and carbon referred to 100 nitrogen, it is seen that they diminish progressively to a depth of 19 feet, the oxygen combined varying from 42·5 to 28·2. The proportion of carbon in the same zone rises from 28·5 to 32·8; a result brought about as much by the carbonic acid disengaged from the minerals as from the gaseous products of the distillation of the charcoal. It is seen that the reduction of the mineral is already considerably advanced at the depth of 19½ feet; and this, so to speak, without any consumption of charcoal, but through the conversion of carbonic acid into carbonic oxide. The hydrogen decreases as the carbonic oxide increases; showing that this gas exercises no influence in the reduction of the ore.

The results obtained by M. Ebelmen from a coke furnace at Seraing were as under: —

No. of experiment - - -	I.		II.	III.	IV.		V.	VI.
Depth - - - - -	1 ft.	1 ft.	4 ft.	9 ft.	10 ft.	10 ft.	12 ft.	45 ft.
Carbonic acid - - - -	11·39	11·39	9·85	1·54	1·08	1·12	0·10	0·00
Carbonic oxide - - -	28·61	28·93	28·06	33·88	35·2	35·35	36·30	45·05
Hydrogen - - - -	2·71	3·04	0·97	0·69	1·72	2·08	2·01	0·25
Carburetted hydrogen - -	0·20	- -	1·48	1·43	0·33	0·29	0·25	0·07
Nitrogen - - - - -	57·06	56·64	59·64	62·46	61·67	61·15	61·34	54·63
Totals - - - - -	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00
Oxygen, per 100 nitrogen -	45·0	45·6	40·0	29·6	30·2	30·6	29·9	41·2
Carbon vapour, per 100 nitrogen	35·2	35·7	33·0	29·4	29·6	30·0	29·9	41·3

I. Gas obtained by plunging an iron tube, three centimetres in diameter, about one foot into the furnace: II. the same; the gas burnt spontaneously: IV. two consecutive analyses of the same gas: V. the gas was collected by an iron tube; VI. gas collected by piercing the masonry two feet above the tuyères; the gas was accompanied by fumes of cyanide of potassium, but no cyanogen could be detached.

The furnace was 50 feet high; the air was supplied through two tuyères, and was

heated to 212°; it was driven at the rate of 26,840 gallons per minute under a pressure of ·5 of mercury. The charges were composed of, unroasted minerals, 1434 lbs.; forge cinders, 1434 lbs.; limestone, 948 lbs.; coke, 1765 lbs. The metal was run every twelve hours, and 17,500 lbs. of white crystalline cast-iron obtained, which was run on thin plates and taken directly to the puddling-furnace. The yield of the mineral was 42 per cent., and the consumption of coke 1500 per 1000 of cast-iron, rising from 1800 to 2000 per 1000 of iron when the furnace was working for foundry iron.

The analyses show a rapid diminution of carbonic acid, and indicate that in the upper regions of the furnace an energetic reduction of ore takes place by the oxide of carbon under the influence of the high temperature of the ascending gases. Between one and nine feet the limestone is calcined. The reduction of the ore takes place at this region by the conversion of carbonic oxide into carbonic acid, without change of volume and without consumption of carbon. The increase in the hydrogen is too small to induce a supposition that aqueous vapour in decomposing can dissolve any notable quantity of carbon. The gases collected at a depth of about 12 feet represent about the mean composition of the gaseous mixture; from that point to a depth of 45 feet, two-thirds of the total height of the furnace, the gases do not sensibly vary, and are composed almost entirely of carbonic oxide and nitrogen. At 12 feet the oxygen is to the nitrogen as 29·9 to 100; in atmospheric air it is as 26·3 to 100. The difference, 3·6, represents the oxygen arising from the reduction of the silicates of iron constituting the forge cinders, which thus is seen to take place between the tuyère and a depth of 12 feet. These silicates are well known to be decomposed with difficulty, but they are reduced at the high temperature prevailing in that zone of the furnace, and their reduction gives rise to a corresponding quantity of carbonic oxide, to a consumption of fuel, and to a considerable absorption of latent heat. The other minerals are reduced higher up in the furnace, and this is common to all coke furnaces, being due to the high temperature of the ascending gases, a temperature much higher than exists in charcoal furnaces, a far larger quantity of combustible being consumed. Hence it is that forge cinders can be successfully used in coke furnaces; while in charcoal furnaces the introduction of small quantities only alters the working of the furnace, makes the iron *white*, and corrodes rapidly the walls of the furnace in consequence of the imperfect reduction.

From his eudiometric experiments on the gases from coke and charcoal furnaces, Ebelmen deduces the following conclusions:—

1. That the amount of carburetted hydrogen is too small to exercise any influence over the chemical phenomena of the furnace.

2. That the atmospheric air thrown into the furnace by the tuyère produces successively carbonic acid and carbonic oxide, at a small distance from the opening. The first of these reactions gives rise to an exceedingly high temperature; the second, on the contrary, causes a great absorption of latent heat, and a corresponding lowering of the temperature of the gaseous current. The limits of the *zone of fusion* bears relation to the space in which the transformation of carbonic acid into carbonic oxide takes place.

3. That the ascending current consisting of carbonic oxide and nitrogen, with a little hydrogen, produces in ascending two distinct effects: it communicates one part of its sensible heat to the materials of the descending column; it becomes charged with all the volatile products disengaged at different heights, and it reduces the oxide of iron to the metallic state. Sometimes this transformation gives rise to an increase in the quantity of carbonic oxide; sometimes, on the contrary, it effects the conversion of carbonic oxide into carbonic acid without change of volume, and without combustion of fuel. Whenever the reduction of oxide of iron takes place with the production of carbonic oxide, there is a consumption of fuel, and an absorption of latent heat. It is essential, therefore, to the good working of the furnace, that the minerals should arrive completely reduced to that part where the temperature is sufficiently elevated for the conversion of carbonic acid into carbonic oxide by contact with carbon; this condition is nearly always realised when the oxide of iron is in a free state in the mineral. The reduction of the oxide when in combination with silica requires, on the other hand, a high temperature, and it can only take place in that zone of the furnace where the carbonic acid has completely disappeared.

4. That the zone where carbonic oxide exists alone is much more extended in coke than in charcoal furnaces, and is nearer the mouth in the former than in the latter: it falls lower, however, in the cylinder with hot blast, the quantity of heat remaining the same.

5. That the volatile gaseous matters from the distillation of the charcoal pass into the escape gases, and exert no influence on the reduction of the minerals.

The mutual relation of the carbonic acid and carbonic oxide, which is observable

in the analyses of Ebelmen, is not found in those of Bunsen and Playfair; this is attributed by Ebelmen to the circumstance that the latter chemists collected their gases through narrow iron tribes, which, becoming intensely heated and partially choked by the fragments of ore and fuel introduced by the rapid stream of gas, so modified the composition of the gases, that the analysis, however carefully conducted, could not represent accurately their real composition. Ebelmen collected his gases through wide tubes, and from the lower parts of the furnace, by piercing the solid masonry. It is obvious, however, that none but very general conclusions can be drawn from the analysis of the furnace gases, in whatever way they may be collected, for their composition cannot be the same under all circumstances, the nature of the fuel, the pressure of the blast, and (as Mr. Parry's experiments prove) the shape of the furnace itself, must each exert an influence in modifying the circumstances which affect their composition. Although, therefore, it is impossible to fix the precise region of the furnace where the reduction of the oxide of iron begins to take place, that is, to define precisely the limits of the "zone of reduction," we may in considering the theory of the production of crude iron divide the furnace into four zones. 1. The zone of reduction; 2. The zone of carburation; 3. The zone of fusion: 4. The zone of oxidation. The zone of reduction will vary in extent, according as the furnace is working with coal or with coke; with hot blast or with cold. The zone of carburation commences just below the top of the bosses, the reduced metal in a soft and malleable state here acquires carbon, its rapid sinking being retarded by the contraction which the sides of the furnace begins to undergo from this point downwards. As the carbonised metal passes through the zone of fusion it melts, together with the earthy matters which serve to protect it from the oxidising effects of the fourth zone, that of oxidation, through which it passes in its passage to the crucible. If the temperature of the zones of fusion and oxidation be not much higher than the melting point of specular iron, the metal in the crucible will be white, with little or no graphite; and if the iron remain sufficiently long in the zone of carburation to take up the maximum quantity of carbon, it will be bright iron. The reduction of silicon appears to take place at about the melting temperature of specular iron: it exists therefore in small quantity in white iron, and in greatest abundance in the grey iron smelted from refractory ores, which require a high temperature.

The proportion of carbonic acid in the gases obtained from different heights in a furnace, has been studied by MM. E. Montefiore Levi and Dr. Emil Schmidt (*Zeitschrift des österr. Ingenieurvereines*, 1852). They found that the zone from which this gas is entirely absent is of very limited extent, for although it is not met with at a height of 8 feet from the tuyère, it exists at 9 feet to the extent of 4·78 per cent., above which point it diminishes up to 15 feet, where it is 0. From this point it again increases, amounting at a height of 30 feet to 3·5 per cent. It then gradually diminishes, until, at a point from 37 to 39 feet above the tuyère, it amounts to only 1·69 or 1·91 per cent.; after which it goes on increasing with rapidity and regularity up to the furnace mouth. The carbonic acid existing in the furnace gases between 15 and 30 feet is referred by these chemists to the decomposition of the limestone used as a flux; and its gradual diminution above this point indicates a reaction of considerable importance, that namely of the carbonic acid upon the ignited coke carbon being taken up and carbonic oxide formed. Now, the quantity of carbon taken up by 275 parts of carbonic acid to convert it into carbonic oxide, amounts to 75 parts, and as in the furnace experimented with, 20,000 kilogrammes of limestone, containing about 8000 kilogrammes of carbonic acid were consumed every 24 hours, a loss of fuel equivalent to 2173 kilogrammes of carbon was daily occasioned by the conversion of this carbonic acid into carbonic oxide, and this may be considered equivalent to 2500 kilogrammes of coke with 11 per cent. of ash. The heat absorbed by the conversion of the carbonic acid of the limestone into a gaseous state is found by calculation, taking the specific heat of carbonic acid at 0·22, and the heating power of coke at 6000, to be equivalent to that developed by the combustion of 322 kilogrammes of coke. Now it was demonstrated by Dulong that the quantity of heat disengaged in the conversion of carbon into carbonic oxide is much *less* than that disengaged in the conversion of carbonic oxide into carbonic acid, although the same quantity of oxygen is required in both cases. The conversion of carbonic acid into carbonic oxide by passing over ignited carbon, is essentially a twofold action; a combination of carbon with oxygen, and a decomposition of carbonic acid into carbonic oxide and oxygen: the former is accompanied by development, the latter by absorption of heat; the latter preponderates to such an extent as to indicate a loss of temperature equivalent to the heat developed by the combustion of 1609 kilogrammes of coke.

These considerations led the authors to employ burnt lime in working blast furnaces, and thus to obviate the loss of heat: the results were not at first satisfactory, the management of the furnace being very difficult, and the slags black and pasty; but

subsequently the working was regular and good, and the saving of coke and the increase of production are stated to have been very evident; moreover the raw iron was of better quality, and all the interior parts of the furnace, especially the tymp stone, remained in a much better state of preservation than when limestone was used. The following table shows the quantity of coke consumed for every 100 kilogrammes of raw iron, and the production during six months. The figures in the first column refer to the furnace, in which limestone alone was used; the second column to the same furnace, in which burnt lime alone was used; and the third column to the furnace in which limestone was used for three months, and burnt lime for the next three months.

	Quantity of Coke in kilogrammes consumed for every 100 kilogrammes raw iron.			Reduction during 28 days, in kilogrammes.		
	1. With Limestone.	2. With burnt Lime.	3. With Limestone.	1. With Limestone.	2. With burnt Lime.	3. With Limestone.
April - - -	165	145	163	436,000	601,000	459,000
May - - -	165	147	159	447,000	582,000	461,000
June - - -	160	147½	164	477,000	588,000	488,000
			With burnt Lime.			With burnt Lime
July - - -	161	146½	149¾	462,000	555,000	537,000
August - -	158¾	145	146	465,000	536,000	552,000
September - -	153	147¾	146	477,000	577,000	600,000
Mean - - -	160½	146¼	154¾	461,000	573,000	516,000
Average from April to June - -	- -	- -	162	- -	- -	469,000
Average from July to September -	- -	- -	147¼	- -	- -	563,000

The very regular and uniform results given in this table, show that by the use of burnt lime, the consumption of coke for every 100 kilogrammes of raw iron was reduced by 14 to 15¾ kilogrammes, while at the same time the production of iron increased, within a certain period, as much as 22 to 24 per cent.

Hitherto the opinion of metallurgists, with regard to the use of burnt lime, was rather unfavourable than otherwise, but since the above experiments were made (at Ougrée), it has been employed with good results in England and Wales, and as much as 12 kilogrammes of coke have, it is stated, been saved for every 100 kilogrammes of limestone, which was replaced by 63 of burnt lime.

Varieties and chemical constitution of cast iron. — In commerce there are four principal varieties of cast iron, known respectively as Nos. 1, 2, 3, and 4, or *dark grey*, *bright grey*, *mottled*, and *white*; these terms, although convenient, do not, however, indicate the intrinsic value of the iron thus denominated, as the variable qualities of ore, fuel, and limestone may exercise such an influence on the resulting crude iron, as to render a low denomination of one manufacturer of greater commercial value than a higher denomination of other makers. The general characters of the four varieties are these:— No. 1. Colour, dark grey, in large rounded grains, obtained commonly near the commencement of the casting when the furnace is in good working order, and when an excess of carbon is present; in flowing it appears pasty, and throws out blue scintillations. It exhibits a surface where crystalline vegetations develop themselves rapidly in very fine branches; it congeals or fixes very slowly; its surface, when cold, is smooth, concave, and often charged with plumbago; it has but a moderate tenacity, is tender under the file, and susceptible of a dull polish. When melted over again, it passes into No. 2, and forms the best castings. No. 2, colour bright grey, of small-grained structure, and interspersed only with small graphite laminæ; possesses great tenacity, is easily filed, turned, and bored; may even be hammered to a certain extent; does not readily crack from change of temperature. No. 3 is a mixture of white and grey iron. On *strongly mottled* iron, little stars and spots of grey iron are found, interspersed in bright or flowery iron; *weakly mottled* iron exhibits white specks on a grey ground. In *streaked iron*, grey iron is found above and below, and bright iron in the middle, with strong demarcations. No. 4. *White iron* varies from tin white to greyish white; it is very brittle, cracking easily, even by change of temperature; it is extremely hard, sometimes even more so than

hardened steel, so that it will resist the strongest file, and scratches glass easily. Fracture sometime laminar, sometimes lamino-radiating, sometimes finely splintered, sometimes dense and conchoidal. As the fracture changes from laminal to conchoidal, the colour likewise varies from white to greyish. Mean specific gravity, 7·5. Expands less than grey cast iron when heated, cannot be welded, because it becomes pasty at the very lowest welding heat. When heated to the melting point it does not suddenly pass into the fused state like grey pig iron, but is converted before fusing into a soft pasty mass. In this variety of pig iron the whole of the carbon is united to the iron; it is never used for casting, but always for conversion into malleable iron. The bright iron obtained from spathic iron ore contains the largest proportion of carbon (5·3 per cent. according to Karsten). A white iron is always the result of a derangement in the working of the furnace, though it by no means follows that when the iron is white the furnace must necessary be in a disordered state, the presence of manganese, for example, has a tendency to make white cast iron; but the quality may be excellent. The white iron resulting from derangement flows imperfectly, and darts out in casting abundance of white scintillations; it fixes very quickly, and on cooling exhibits on its surface irregular asperities, which make it extremely rough; it is exceedingly hard, though it is easily broken; the fracture being radiated and lamellar; the bar iron it affords is of inferior description. This kind of iron is always produced when the furnace is carrying a heavy burden of forge cinders containing sulphur and phosphorus.

Thus there are two distinct kinds of white cast iron: 1st. That obtained from ores containing a large proportion of manganese crystallising in large plates; this variety is highly prized for making steel. 2nd. That resulting from a heavy mineral burden, or from a general derangement of the furnace, or from the rapid chilling of fused grey iron crystallising in small plates; both are hard and brittle, the first more so than the last. Cast iron, which by slow cooling is grey, becomes white when it is cooled rapidly; on the other hand, when white iron is melted and allowed to cool very gradually, a portion of the carbon crystallises out as graphite, and grey cast iron is produced.

In some iron works *six* varieties of pig iron are recognised, which may be classified thus: —1. First foundry iron, large crystals; 2. Second foundry iron, large and small crystals mixed; 3. Dark grey, all small crystals; 4. Bright grey; 5. Mottled; 6. White, verging on mottled.

The subjoined table exhibits the composition of some different varieties of Continental, English, and American crude irons. The methods of determining the various elements which nearly always accompany cast iron, are given at the end of this article.

		Description.	Iron.	Carbon, combined.	Carbon, free.	Phosphorus.	Sulphur.	Silicon.	Manganese.	Total.	Sp. Gr.
German	a.		93·66	0·48	3·85	1·22	trace.	0·79	trace.	100·00	7·077
	b.		93·29	2·78	1·99	1·23	,,	0·71	,,	100·00	7·43
	c.		91·42	1·44	2·71	1·22	,,	3·21	,,	100·00	7·16
French	d.		95·18	- -	3·40	0·45	0·03	0·80	,,	99·86	
	e.		93·39	1·00	0·18	0·38	3·75	1·30	,,	100·00	
American	f.		94·87	·04	3·07	·22	trace.	1·80	,,	100·00	7·159
	g.		96·35	1·14	1·50	·21	·01	·79	,,	100·00	7·54
	h.		96·55	2·79	- -	·17	·06	·32	,,	99·89	7·67
Silesian	i.		91·45	4·94	- -	·12	trace.	·75	3·38	100·64	7·53
	j.		90·75	3·62	- -	3·26	,,	·25	2·00	99·88	7·6
Scotch	k.		92·63	1·40	1·20	1·20	,,	1·40	- -	100·73	
	l.		92·06	2·62		0·46	0·04	3·82	1·80	100·81	
	m.		92·76	2·80		0·79	0·04	2·88	1·80	100·77	
English	n.		89·45	2·30		0·57	0·02	4·88	2·22	99·44	
	o.		94·10	1·67	1·92	0·21	trace.	1·30	1·12	100·52	
Welsh	p.		95·27	2·42		1·08	0·87	0·36	- -	100 00	
	q.		93·55	2·80		1·66	0·14	1·85	- -	100·00	
	r.		91·92	4·00		0·07	0·01	0·21	3·65	98·86	
	s.		86·00	4·23		0·06	0·00	0·62	8·40	99·31	
	t.		91·29	4·17		0·07	0·01	0·21	4·11	99·86	
	u.		94·71	1·21		1·34	2·64	0·10	- -	100·00	

a, *Very grey pig*, from Leerbach in the Hartz, cold blast; *b*, *Mottled* iron, from the royal works in the Hartz, cold blast; *c*, *Normal* grey pig, from the same works, hot blast; *d*, Grey charcoal pig, cold blast; *e*, White pig, from Firmy, very short and brittle; *f*, American grey pig, charcoal; *g*, American *mottled* iron; *h*, American charcoal, white iron; *i*, Silesian white charcoal iron, very crystalline; *j*, The same, but less crystalline; *k*, Grey Scotch coke pig, from the Calder iron works; *l*, Scotch coke, No. 3 pig iron; *m*, Glengarrick, No. 3 pig; *n*, Coalbrookdale Lightmoor best first foundry iron; *o*, Grey pig iron, from Dudley, Staffordshire; *p*, Ordinary Aberdare white pig; *q*, Grey cinder pig; *r*, White crystalline pig iron, smelted from manganiferous ore; *s*, The same; *t*, The same; *u*, Ordinary white pig.

Besides the substances enumerated in the above table, other metals, such as copper, arsenic, chromium, titanium, cobalt, zinc, tin, aluminium, and the metals of the alkalies

and alkaline earths, are occasionally found in crude iron, but very rarely in quantities that can at all affect the qualities of the product. The elements, the quantitative estimation of which has been given in the above analyses, *do*, however, materially modify the physical qualities of cast iron. We shall, therefore, offer a few observations on each.

1st. *Carbon.*—Iron can take up any quantity of carbon up to a little over 5 per cent., at which point it becomes saturated; the compound thus formed is the white crystalline pig or specular iron (*i*) (*r*) (*s*) (*t*); when absolutely pure its composition is 94·88 iron and 5·12 carbon, it is a *tetra-carburet*, Fe^4C. The most highly carburetted iron which Faraday and Stodart could produce, consisted of iron 92·36 carbon 5·64. There seems no reason for admitting, as some metallurgists have done, the existence of a polycarburet of iron containing 18·3 per cent. of carbon, inasmuch as iron containing under 6 per cent. appears to be completely saturated. The specific gravity of pure tetra-carburet of iron is 7·66; it is the most fusible of all the carburets of iron, its melting point being 1600° Centigrade; it is brittle and silver white, and crystallises in oblique prisms, which are frequently tabular. According to Gurlt the carburet of iron existing in grey pig is the *octo-carburet*, Fe^8C, the crystals of which belong to the regular or cubic system, but almost always appear in grey iron in the form of confused octohedral groups. The specific gravity of pure octo-carburet of iron, according to the same authority is 7·15, and its composition 97·33 iron and 2·63 carbon; its colour is iron grey, its hardness is inferior, and its fusibility less than that of specular iron; the groups of crystals often found in cavities in large castings are composed of this peculiar carburet. Gurlt very ingeniously endeavours to show that in grey pig-iron the carbon of the octo-carburet is partially replaced by *silicon, sulphur*, and *phosphorus*, and the iron by manganese and other metals. In like manner the carbon of the *tetra-carburet* may be partially replaced by silicon, phosphorus, or sulphur, the eliminated carbon appearing in the form of graphite: the same decomposition is effected by heat, and specular iron, if exposed to a temperature considerably above its fusing point, becomes *grey*; if cooled slowly, the graphite separates in large flakes, if rapidly, in minute particles. Some metallurgists suppose that in grey cast iron, a portion only of the iron is chemically united with carbon, the rest of the metal being dissolved in the carburetted compound in the form of malleable iron: we incline however to the opinion of Gurlt, that the whole mass of the iron is in a state of combination with the electro-negative constituents, such as carbon, sulphur, phosphorus, and silicon. Thus in the white pig-iron of heavy burden (*u*), there is a deficiency of carbon, that element being replaced by sulphur and phosphorus.

Karsten gives as the mean of several analyses, 3·5865 per cent. as the quantity of carbon in cast-iron smelted with charcoal from spathic ore. He states, that iron containing as little as 2·3 per cent. of carbon still retains the properties of cast-iron, particularly the faculty of separating graphite when allowed to cool slowly. With 2 per cent. of carbon iron is not forgeable, and scarcely so if it contain only 1·9 per cent. With this quantity of carbon it is steel, though not of the weldable kind (cast steel); even with so small a proportion of carbon as 1·75 per cent. it is weldable only in a slight degree; the latter property increases as the hardness of the iron decreases. An amount of from 1·4 to 1·5 per cent. of carbon in iron denotes the maximum of both hardness and strength. Iron containing 0·5 per cent. of carbon is a very soft steel, and forms the boundary between the steel (*i. e.* iron which may yet be hardened) and malleable or bar iron. These limits lie perceptibly higher if the iron be pure; and lower if it contain silicon, sulphur, and phosphorus.

The composition of the various carbides of iron, according to Berthier, is as under:—

	FeC^3.	FeC^2.	FeC.	Fe^2C.	Fe^4C.	Fe^6C.
Iron -	0·600	0·690	0·819	0·899	0·947	0·9643
Carbon -	0·400	0·310	0·183	0·101	0·053	0·0357

In the blast furnace, the reduced iron may take up carbon in two different ways; 1. By immediate contact with the incandescent fuel; and 2. By taking carbon from carbonic oxide; thus $Fe + 2CO = FeC + CO^2$. That iron decomposes carbonic oxide is considered by Le Play and Laurent, to be proved by the following experiment: pure oxide of iron and charcoal were heated in two *separate* porcelain boats, placed in a glass tube; the air in the tube furnished oxygen to the carbon; carbonic oxide was formed, which was converted into carbonic acid, at the expense of the oxygen of the oxide of iron; the carbonic acid was again transformed into carbonic oxide, by taking up a fresh quantity of carbon, which was again converted into carbonic acid by taking oxygen from the oxide of iron, and this went on until the whole of the oxide of iron was reduced, the metallic iron then decomposed carbonic oxide, producing carbonic acid and carbide of iron; and this went on till a certain quantity of carbon had combined with the iron, when the action ceased. If the charcoal be very strongly ignited previous to the experiment, the carbonisation of the

iron does not take place, neither does pure carbonic oxide carbonise iron when passed over the metal at a red heat: the effect in the experiment above described may therefore be due to the carburetted hydrogen evolved from the charcoal. Iron begins to take up carbon when heated only to the softening point, the carbon gradually penetrates the metal, converting it first into steel and then into cast-iron; conversely melted cast-iron gives up carbon to soft iron, which it converts into steel. When white iron (Fe^4C) is heated with acids, nearly the whole of the carbon is eliminated in combination with hydrogen. Grey iron only gives up to hydrogen the carbon which was chemically combined with the iron, the uncombined carbon or graphite remains unacted upon; the dark spot produced upon grey iron by a drop of nitric acid arises from this separation of graphite. For the amounts of carbon in the different varieties of steel, see STEEL.

Phosphorus.—In very few specimens of crude iron is this element wholly absent; when it exists in small quantities only, it is said rather to improve the iron for castings, as it imparts to the metal the property of fusing tranquilly; in a larger proportion it weakens the iron. In like manner a very small quantity of phosphorus hardens bar iron without materially influencing the other properties, but when it exceeds ·5 per cent. it renders the bar brittle, *cold-short*, as it is termed. According to Schafhaeutl, both cast-iron and steel are improved by phosphorus and by arsenic; he found the latter in the celebrated Dannemora iron, and in the Lowmoor iron, and the former in the equally famous Russian (CCND) iron.

Sulphur.—This element imparts to crude iron the property of becoming viscid, and of solidifying quickly with cavities and air-bubbles. It is not certain to what extent, or if at all, the presence of minute proportions of sulphur reduces either the tenacity or the toughness of cast-iron of given quality in other respects. It is stated in the Report of the Commission of Inquiry, as to the manufacture of ordnance on the continent, on the authority of Schür and Mitscherlich, that in certain Swedish works *pyrites* is thrown into the furnace with the other constituents of the charge, to produce the fine grey *mottled* iron required for gun founding, and it is added that the effect may be analogous to that of the oxidising flame in a reverberatory furnace. It is certain that sulphur possesses the property of concentrating carbon in iron: and as mottled iron is a mixture of white and grey iron, it is not difficult to see how the addition of pyrites may determine the formation of this variety of cast-iron in a furnace, which without it would produce grey iron only: but it is scarcely credible that any intelligent founder would resort to such a method of making iron for casting cannon, in which the highest possible degree of tenacity is required. The fine grey mottled iron, which from its tenacity is known to be best fitted for large castings, is said to be prepared without difficulty, by charging the furnace partly with roasted and partly with raw ore, and so regulating the blast that the yield shall be regular, and the slag nearly colourless; these two ores, having different degrees of fusibility, are reduced after different periods in the furnace, and hence afford one of them grey, and the other white iron, the result being, provided the minerals are properly proportioned, a mottled iron, harder and more tenacious than grey iron, obtained by mixing or by smelting in the cupola. It is desirable that the temperature of the furnace should be kept as low as possible, the production of dark grey graphitic iron resulting always from intensity of heat.

When sulphur is melted with iron containing the largest amount of chemically combined carbon, sulphuret of iron is formed on the surface; underneath a layer of graphite, and beneath that, a layer of iron with the *maximum* of carbon: and when *grey* iron containing 3·31 per cent. of graphite is melted with sulphur, *white* iron, containing iron 94·03, combined carbon 4·93, and no graphite, is formed. The tendency of sulphurous ores to produce white metal in their treatment in the blast furnace, has long been known; it was supposed that this was occasioned by the too great fusibility which the sulphur gave to the cast iron, but ores containing large proportions of phosphoric acid will produce very grey iron, notwithstanding their fusibility, so that this explanation does not serve; the experiments above described point to the true reason. The sulphur present in the ore (if as sulphuric acid reduced in the furnace) enters into combination with the iron, displacing a corresponding proportion of carbon, which becomes concentrated in the remainder of the metal, forming white iron. To guard against this, and in order to obtain a metal which shall contain a *minimum* amount of sulphur, the slags should contain the *maximum* amount of lime, M. Berthier having shown that this earth decomposes sulphuret of iron at a high temperature, in the presence of carbon. M. Janoyer states, that the proportion of lime and silica in the slag may be as 54 to 36; it is doubtful whether such a highly basic cinder would be sufficiently fusible. Direct experiments, however, have shown that the amount of sulphur in cast-iron diminishes in proportion as the amount of lime in the slag increases. A still better flux is oxide of manganese, and it is found that when the

manganiferous spathose ore constitutes part of the burden of the furnace, sulphur almost entirely disappears from the crude iron. M. Janoyer believes that he has proved experimentally, that the whitening of cast-iron smelted from sulphurous ores, is due, in part at least, to the subtraction of a portion of its carbon, and its volatilisation in the form of sulphuret of carbon, by which the temperature of the furnace is lowered; but his experiments on this point require confirmation. The presence of a very small quantity of sulphur acts very injuriously upon bar iron, so small a proportion as $\frac{1}{1000}$ rendering the metal "hot short," that is, incapable of being worked at a red-heat under the hammer. If the quantity of sulphur in the crude iron exceeds 0·4 per cent., it is scarcely possible to manufacture it into good wrought iron.

Silicon.—Like carbon this element enters into combination with iron in all proportions up to as high as 8 per cent. The largest quantity found by Karsten in pig-iron was 3·46 per cent., but in the above table a specimen (s) is quoted from Coalbrook Dale containing 4·88 per cent.: and we have lately found it in a sample of Nova Scotia iron as high as 5·8 per cent. Generally speaking, grey cast-iron contains more silicon than white, and the greater the quantity of graphite in the crude iron the larger the amount of silicon, because the higher the temperature of the furnace; but this again will depend materially on the quality of the coal, from the ash of which the silicon is probably principally derived. A clean strong coal yielding a small per centage of ash furnishes a cast-iron with less silicon than an inferior coal, the mineral burden being the same. Pig-iron smelted with hot blast contains more silicon than when the blast is cold, because of the higher temperature which prevails in the fusion zone of the furnace. Some analyses illustrating this fact have been already given. According to the experiments of MM. Janoyer and Gauthier the amount of silicon in hot blast cast-iron may be greatly influenced by varying the proportion of limestone in the furnace. Pig-iron obtained with a charge yielding a cinder in which the lime and alumina were to the silica as 7 is to 10, had little strength, breaking readily, and analysis showed that it contained 3 per cent. of silicon. By increasing the amount of lime in the charge, so as to obtain a cinder in which the bases were to the silica as 8 is to 10, and at the same time employing a blast of the highest attainable temperature, the iron produced had a much greater strength. When the proportion of bases to silica in the cinder was as 20 is to 19, the iron contained only an inappreciable amount of silicon, and the strength was increased in the proportion of 65 to 45. When the maximum quantity of lime was used the consumption of fuel was on the average increased to the extent of 6 per cent.

On reading the above account of the experiments of Messrs. Janoyer and Gauthier, the writer of this article induced the furnace manager of the Blaina Iron Works to increase the yields of lime on one of his furnaces to as great an extent as in his judgment it would bear, and when the furnace was under the full influence of the excess of flux to forward him samples of the grey pig for analysis. The following results show that, contrary to the statement of MM. Janoyer and Gauthier, no advantage, as regards a diminution in the amount of silicon, was hereby obtained, the proportion of that element being not perceptibly altered, though there is a slight diminution observable in the percentage of sulphur.

	Grey pig, with usual burden of lime.	Grey pig, with extra burden of lime.
Sulphur	0·067	0·045
Silicon	2·900	2·930

As the presence of silicon in pig-iron affects in a remarkable degree the yield as well as the strength of puddled bars, it is of importance that this element should be removed as effectually as possible by a refining process before the crude iron is submitted to the puddling process. Pigs with 3 per cent. of silicon give about 6 per cent. of silica, and this requires somewhere about 12 per cent. of iron to form a cinder sufficiently fluid to allow the puddled iron to become aggregated into balls; this can of course be obtained only by *burning* that amount of iron in the puddling furnace after the expulsion of the carbon, and while the mass is in a powdery state. This powdery mass is composed of small granules of iron mixed up with a *glucy* infusible cinder. The puddler turns over this mass repeatedly to expose the iron to the oxidising influence of the furnace; the silica now taking up sufficient oxide of iron to give it fluidity begins to separate from the iron, and forms a pool at the bottom. After some time the puddler, finding the mass of cinder accumulating pretty fast, makes the first attempt to "ball up." In order to save as much iron as possible, he keeps the damper down and works the powdery mass at as low a red heat as possible. The balls, even when made, will not bear much heat under the hammer without falling to pieces. hence an imperfect weld in the hammered mass and rolled bar is the result, and although the iron may be chemically pure it is deficient in *strength*. By protracting the process and wasting more iron, there is no doubt but that the iron might be im-

proved, for the cinder would become richer in oxide, more fluid, and consequently offer less resistance to a perfect weld. Iron, on the contrary, with a small percentage of silicon may be "balled up" directly it is "dried," and the short time required for that operation can be conducted at the highest heat of the furnace. A good welding of the mass is the consequence: such iron is *strong*, and the labour of the puddler in obtaining it is much less than in the former case. Every pound of silica must have twice its weight of iron to form a cinder sufficiently rich in oxide to allow the particles of iron to become properly agglutinated. Such being the influence of silicon on both the yield and the strength of wrought iron, and such being the waste attendant on its removal in the refinery, it becomes an object of much practical importance to prevent as far as possible the formation of a silicide of iron in the blast furnace, and the observations of MM. Janoyer and Gauthier on this point require careful verification.

Manganese.—The presence of this element in pig-iron does not appear to exert much influence either for good or for bad on the quality of the metal, and even when it exists in quantity amounting to 4 or 5 per cent. in the crude iron, it disappears almost entirely during the conversion of the cast-iron into wrought or malleable. It has already been observed that the cinder from iron smelted from manganiferous ores contains, generally speaking, more sulphur than slags or cinders from iron ores containing no manganese. We have had numerous opportunities of confirming this, and have therefore on this account alone attached much importance to the existence of manganese in iron ores; but our attention has more recently been directed to another point which we think especially worth of notice of iron manufacturers, namely, to the almost perfect removal of phosphorus from pig-iron containing a very large proportion of that element, and at the same time a high percentage of manganese. As our experiments on this important point are still in progress, we shall merely here quote a few in illustration of the purifying action we have alluded to.

Iron made from a highly phosphorised ore containing no manganese:—

	Phosphorus per cent.
Pig	3·030
Puddled bar	0·838
Rough down bar	0·572

The finished bar was cold short in the highest degree, it was in fact nearly worthless.

Iron made from a highly phosphorised ore containing a large per-centage of manganese.

	Phosphorus.	Manganese.
Pig	2·60	7·20
Puddled bar	0·30	0·30
Do.	0·20	
Finished bar	0·11	

The iron was carefully watched during the puddling process. It melted very thin, and took rather more work than usual; as soon as the boiling commenced it was very violent, the metal forcing itself out of the door hole until it was checked. When it "came to nature," as the workmen term it, it worked beautifully and stood any amount of heat, in fact the heat could with difficulty be raised to the requisite degree. The yield was 22 cwts. 2 qrs. 24 lbs. of pig to produce one ton (of 20 cwts.) of puddled bar; this is about the yield of good mine iron when properly puddled. The finished bar exhibited none of the cold short quality, it was exceedingly ductile, indeed excellent horseshoes were made from it. The puddling cinder had the following composition:—

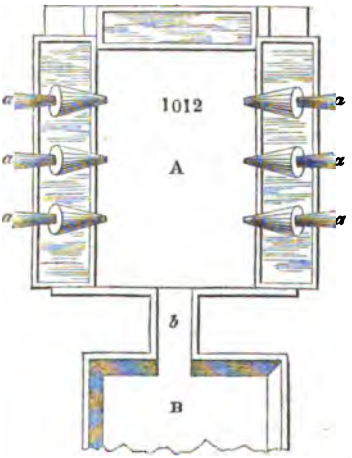
Silica	8·240
Protoxide of iron	70·480
Oxide of manganese	12·800
Phosphoric acid	7·660
Sulphur	·535
	99·715

Other observations have shown that highly manganiferous pig (without phosphorus) is puddled with difficulty, and sometimes with considerable waste, so that the advantages of an alloy of manganese would seem to be confined to those varieties of crude iron into the composition of which phosphorus largely enters.

The Conversion of Crude or Carburised Iron into Malleable Iron.—This is effected by one or more operations, which are necessarily of an oxidising nature, the object being to eliminate from the cast iron the carbon in the form of carbonic oxide gas, and the silicon, sulphur, phosphorus, and other foreign bodies in the form of oxidised

products, which pass either partially or wholly into the scoriæ or cinders. The pig-iron is either subjected to a preliminary decarburation in the oxidising blast hearth, or "refinery," and the operation thus commenced afterwards completed in the oxidising air-furnace, or "puddling furnace;" or the complete conversion of the crude iron is effected by one operation in the puddling furnace, by the process called "boiling." It is said (*Blackwell*) that, at several works abroad, the attempt to arrest the progress of decarburation in the puddling or boiling furnace at that point in which the conversion has proceeded only so far as to leave the iron in the state of steel, or subcarburet, has been successful, and that a valuable natural or puddled steel, not requiring cementation before conversion into refined or cast steel, has been the result.

English Method of refining.—The finery furnace is composed of a body of brickwork, about 9 feet square, rising but little above the surface of the ground. The hearth, the bottom of which is of millstone grit, placed in the middle, is 2½ feet deep; it is rectangular, being in general 3 feet by 2, with its greatest side parallel to the face of the tuyères, and it is made of cast iron in four plates. On the side of the tuyères there is a single brick wall, on the three sides sheet iron doors are placed, to prevent the external air from cooling the metal, which is almost always worked under an open shed or in the open air, but never in a space surrounded by walls. The chimney, from 15 to 18 feet high, is supported upon four columns of cast iron; its lintel is 4 feet above the level of the hearth, in order that the labourers may work without restraint. The air is supplied by the blowing cylinders which supply the blast furnace, and enter the hearth through 6 tuyères, so arranged that the current issuing from those on the opposite sides of the crucible are not disposed in the same plane. These tuyères, like those in the furnaces in which cast iron is made, are provided with double casings, through which a current of cold water is constantly flowing, and each pipe is furnished with a suitable stop valve for regulating the volume of the blast. The tuyères are placed at the height of the lip of the crucible or hearth, and are inclined towards the bottom, at an angle of from 25° to 30°, so as to point upon the bath of melted metal as it flows. The quantity of air blown into the fineries is considerable, being nearly 400 cubic feet per minute for each finery. The ground plan of a finery is shown in *Fig.*1012, A being the hearth, *b* the tapping hole, B the chill mould, and *a a a a a a* the nozzles of the tuyères. The operation of refining crude iron is conducted as follows: A fire is lit in the centre of the hearth, which is first urged by a gentle blast; a charge of pig, about 2 tons, is then laid on, and the whole is covered up dome-form with a heap of coke; the full power of the blast is now turned on, the cast iron melts, and flowing down gradually collects in the crucible, more coke being added as the first quantity burns away. The operation proceeds by itself, the melted metal is not stirred about as in some modes of refinery, and the temperature is always kept high enough to preserve the metal liquid. During this stage the coals are observed continually heaving up, a movement due in part to the action of the blast, but in part to an expansion caused in the metal by the discharge of carbonic oxide gas. When all the pig-iron is collected at the bottom of the hearth, which happens in about two hours, it is blown vigorously for some time longer, the tap-hole is opened, and the *fine* metal runs out with the slag into the chill mould, or pit, as it is called, which has been previously washed with a thin clay liquid, to prevent the refined metal from adhering to its surface. The chill mould is in a prolongation of the tapping hole; it is a heavy cast iron trough, about 10 feet long, 3 feet broad, and 2 to 2½ inches deep. The slag, from its inferior specific gravity, forms a crust on the surface of the metal: its separation is facilitated by throwing cold water in large quantities on the fluid mass immediately that the entire charge has left the refinery. This sudden chilling of the metal makes it exceedingly brittle, so that it can be broken into smaller pieces by heavy hammers, for the subsequent operation of puddling. The refined metal is very white, hard, and brittle, and possesses in general a fibrous radiated texture; or sometimes a cellular, including a considerable number of small spherical cavities, like a decomposed amygdaloid rock. The loss of iron in the refinery process is very large, varying from 10 to 20 per cent. In the Welsh iron works, 1 ton of white iron takes from 1¾ to 2 hours to refine, the consumption of coke being



from 6 to 8 cwts., and the loss about 3 cwts. Grey iron takes from 7 to 9 cwts. of coke per ton, the time required to refine being from 2½ to 3 hours, and the loss of iron per ton 4 cwt. The pig-iron to be decarburised in the refinery is frequently mixed with rich silicates (forge cinders), and occasionally with oxides of iron, the object being to protect the melted metal in some degree from the oxidising effects of the blast, and to react on the carbon which it contains. The quantity employed depends on the degree to which the pig-iron is carburised. The crude iron, from which wrought iron of the best quality is produced, is that possessing a medium degree of carburation, or what is generally termed grey pig-iron. White iron, which possesses an inferior degree of fluidity to grey pig-iron, and which comes as it is termed more rapidly to nature, is that quality which is most generally employed in the manufacture of wrought iron, especially when the conversion is effected in the single operation of boiling in the puddling furnace; but this species of pig-iron being the result of imperfect re-actions in smelting, is always more impure than grey iron obtained from the same materials, and does not produce wrought iron of the best quality.

The coke employed in the refinery should be as free as possible from shale, and should contain only a low percentage of ash; it should especially be free from sulphuret of iron, which it often contains in considerable quantity, as it is found that nearly the whole of this sulphuret enters into combination with the metal, and does not pass off in the slags.

Refineries are sometimes worked on hot fluid iron, run direct from the hearth of the blast furnace, a considerable saving, both of time and fuel, being hereby effected. Various proposals have been patented for the employment of fluxes to assist in the removal of the impurities of cast iron, both in the refining and puddling furnaces. Thus Mr. Hampton patented, in 1855, a flux, prepared by slaking quick lime with the solution of an alkali, or alkaline salt. MM. Du Motay and Fontaine propose, in a patent secured in 1856, to purify and decarbonise iron in the refining and puddling furnace, by the employment of fluxes prepared from the scoriæ of the puddling furnace, from oxides of iron and silicates or carbonates of alkalies, or other bases. Mr. Pope (1856) proposes to add the residue obtained by the distillation of Boghead or Torbane mineral, to such fuel as is employed in the refining of iron. Mr. Sanderson, of Sheffield (1855), employed for the refining of iron such substances as sulphate of iron, capable of disengaging oxygen or other elements, which will act upon the silicium, aluminum, &c., contained in the metal. These and various other schemes have been suggested with the object of lessening the enormous waste which pig-iron undergoes on its passage through the refinery; for as the process is at present conducted, the partial elimination of the carbon, sulphur, phosphorus, &c., is only effected at the expense of a large quantity of iron, which is oxidised by the blast, and passes in the form of silicate into the slag; the desideratum is the discovery of some method of reducing the oxide of iron, and substituting for it some other base, which will form with silica a sufficiently fusible silicate. Mr. Blackwell suggests that the decarburation of pig iron might be effected by remelting it in a cupola furnace, either alone, or with minerals containing nearly pure oxides of iron; the oxide of iron would be reduced by the carbon of the pig-iron, while the silicates of the fuel, with the silica, alumina, and other easily oxidisable alloys eliminated from the crude iron, would be separated in the form of fusible earthy glass. The employment of steam as a purifying agent for crude iron has been patented by several persons. Mr. Nasmyth in 1854 obtained a patent for the treatment of iron in the puddling furnace with a current of steam, which being introduced into the lower part of the iron, passes upwards, and meeting with the highly heated metal undergoes decomposition, both elements acting as purifying agents. The steam employed is at a pressure of about 5 pounds per square inch, and passes into the metal through a species of hollow rabble, the workman moving this about in the fused metal until the mass begins to thicken, which occurs in from five to eight minutes after the introduction of the steam; the steam pipe is then removed and the puddling finished as usual.

The advantages are said to consist in the time saved at each heat or puddling operation (from ten to fifteen minutes); the very effective purification of the metal; and the possibility of treating highly carbonised pig-iron at once in the puddling furnace, the preliminary refining being thus avoided. In October 1855, Mr. Bessemer patented a somewhat similar process for the conversion of iron into steel, the steam highly heated, or a mixture of air and steam, being forced through the liquid iron run from the furnace into skittle pots, steam being used only at an early stage of the process, and the treatment finished with heated air. In the early part of the same year Mr. Martien of New Jersey obtained a patent for a partial purification of crude iron, by causing air or steam to pass up through the liquid metal, as it flows along gutters from the top hole of the furnace or finery forge; and he subsequently proposed to include with the air or steam, other purifying agents, such as chlorine, hydrogen, and coal gas, oxides of manganese, and zinc, &c. Other methods of treating crude iron with air and

steam were made the subjects of patents by Mr. Bessemer in December 1855 and January 1856. In October a patent for the employment of steam in admixture with cold blast in the smelting furnace and fining forge, was obtained by Messrs. Armitage and Lee, of Leeds, and in August a patent was obtained by Mr. George Parry, of the Ebbw Vale Iron Works, for the purification of iron by means of highly heated steam. The fluid iron is allowed to run into a reverberatory furnace previously heated, and the steam is made to impinge upon it from several tuyères, or to pass through the metal. Steel is to be obtained by treating highly carburetted iron with the steam, and then running it into water, and fusing it with the addition of purifying agents, or adding to it in the furnace a small quantity of clay, and afterwards about 10 or 15 per cent. of calcined spathose ore. Mr. Parry observing that when steam was sent through the molten iron, as in Mr. Nasmyth's process, the iron quickly solidified, conceived the idea of communicating a high degree of heat to the steam by raising the steam pipe a couple of inches above the surface of the metal, so that it might be exposed to the intensely heated atmosphere of the furnace; and also of inclining the jet at an angle of 45°, so as to give the molten mass a motion round the furnace while the pipe was maintained in the same position at a little distance beyond the centre: when this was done, in a few minutes the iron began to boil violently, the rotatory motion of the fluid bringing every part of it successively into contact with the highly heated mixture of steam and atmospheric air, and no solidification taking place. Having thus ascertained the proper way of using steam as a refining agent, it occurred to Mr. Parry that, as the presence of silicon in the pigs for puddling affects in a remarkable degree the yield of iron, as well as its strength, it is a matter of consequence that this element should be removed as completely as possible previous to the puddling operation; the steaming of the iron would probably therefore be more profitably applied in the refinery than in the puddling furnace. Pig iron containing 3 per cent. of silicon gives 6 per cent. of silica, which, to form a cinder sufficiently fluid to allow the balling up of the iron, would require from 10 to 12 per cent. of iron; and this can, of course, only be obtained by burning that amount of iron in the puddling furnace, after the expulsion of the carbon, and while the mass is in a powdery state. The superheated steam is injected on the surface of the iron in the refinery by water tuyères, similar to those used for hot blast at smelting furnaces; they are inclined at an angle of about 45°; some are inserted at each side of the door of the furnace, and are pointed so as to cross each other, and give the iron a circulating motion in the furnace. The tuyères are from ⅜ to ½ an inch in diameter; a little oxide of iron or silicate in a state of fusion on the surface of the iron accelerates the action, as in common refineries, and increases the yield of metal, but to a much greater extent than when blasts of air are used. The steam having been turned on, the mass of iron commences circulating around the inclined tuyères, and soon begins to boil, and the action is kept uniform by regulating the flow of the steam. The most impure oxides of iron may be used in this process, such as tap cinder or hammer slag from puddling furnaces, without injury to the quality of the refined metal made; the large quantities of sulphur and phosphorus which they contain being effectually removed by the detergent action of the heated steam. When 4 cwt. of cinders are used to the ton of pig, 20 cwt. of metal may be drawn, the impurities in the pig being replaced by refined iron from the cinders.

We have had several opportunities of witnessing this beautiful refining process at the Ebbw Vale Iron Works, and have made the following analysis of the cinders and metal which fully bear out the above statements:—

	Pig iron.	Refined metal.
Graphite	2·40	0·30
Silicon	2·68	0·32
Slag	0·68	0·00
Sulphur	0·22	0·18
Phosphorus	0·13	0·09
Manganese	0·86	0·24

	Forge cinders thrown into the refinery.	Cinder run out of the refinery.
Sulphur	1·34	0·16
Phosphoric acid	2·06	0·129

A ton of grey iron may be refined by steam in half an hour, using seven jets of steam ¾ of an inch in diameter, and with a pressure of from 30 to 40 lbs.; the temperature of the steam being from 600° to 700° F., the orifices of the tuyères being 2 or 3 inches above the surface of the iron. As the fluidity of the metal depends upon the heat which it is receiving from the combustion of the fuel in the grate, and not on any generated in it by the action of the steam, it is evident that the supply of the latter in a given time must not exceed a certain limit, or the temperature of the fluid iron will become reduced below that of the furnace. This however partly regulates itself,

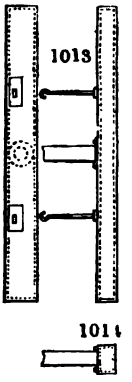
and does not require much nicety in the management, for, if too much steam be given, the ebullition becomes so violent, as to cause the cinders to flow over the bridges, giving notice to the refiner to slack his blast. The "forge cinders" used in the steam refinery contain 66 per cent. of iron; the "run out" cinder contains only 26; 40 per cent. of iron, or thereabouts, have therefore been converted into refined metal, and the resulting cinder is as pure as the ordinary Welsh mine, with its yield of 25 per cent. of iron. The following is the result of one week's work of the steam refinery:—

	cwt.	qrs.	lbs.
Pigs used	396	0	15
Metal made	393	3	1
Loss	2	1	14
Yield	20	0	14

The quantity of cinder (puddling) used was 3½ cwt. per ton of pig. When 1½ cwt. of cinders were used to 1 ton of pig, the yield was invariably 20 cwt. over a make of about 100 tons.

Refining by gas (German method). — The most simple form of gas reverberatory furnace is that known as Eck's furnace, which is employed at the government works of Gleiwitz and Königshütte, for refining iron made on the spot. The following description and plan of this furnace is extracted from a report to the secretary of state for war, from the superintendent of the Royal Gun factories, Colonel Wilmot, R. A., and the chemist of the War Department, Professor Abel.

The gas generator (which replaces the fire-place of the ordinary reverberatory furnace) is an oblong chamber, the width of which is 3 feet 9 inches, and the height from the sole to the commencement of the sloping bridge 6 feet 4 inches. It tapers slightly towards the top, so as to facilitate the descent of the fuel, which is introduced through a lateral opening near the top of the generator. Its cubical contents are about 44 feet.

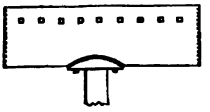


The air necessary for the production of the gas is supplied by a feeble blast, and enters the generator from the two openings or tuyères of a long air chest of iron plate (*figs.* 1013, 1014, 1015) fixed at the back of the chamber, near the bottom. The space between the air chest and the sole of the chambers serves as a receptable for the slag and ash from the fuel. There are openings on the other side of the chamber, opposite the tuyères, which are generally closed by iron plugs, but are required when the tuyères have to be cleaned out. There is an opening below the air-chest, through which fire is introduced into the chamber, when the furnace is set to work, and which is then bricked up, until at the expiration of about 14 days it becomes necessary to let the fire die out, when the slag and ash which have accumulated on the sole of the chamber are removed through this opening.

The hearth of the furnace is constructed of a somewhat loamy sand; its general thickness is about 6 inches, its form is that of a shallow dish, with a slight incline towards the tap hole; the iron is prevented from penetrating through the hearth by the rapid circulation of cold air below the fire-bridge and the plate of the hearth.

Figs. 1016 and 1017, represent the upper oblong air-chest provided with a series of tuyères, which enter the top of the furnace just over the fire-bridge at an angle of 30°. The air forced into the furnace through these tuyères serves to inflame and burn the gases rushing out of the generator, and the direction of the blast throws the resulting flame down upon the metal on the hearth, in front of the bridge. This air-chest communicates, like the other one, by pipes, with the air accumulator of the neighbouring blast furnace. The amount of pressure employed is about 4 lbs.; but the supply of air, both to the generator and the inflammable gases, admits of accurate regulation by means of valves in the connecting pipes. There is an opening in the arch at both sides of the furnace, not far from the bridge, into which, at a certain stage of the operations tuyères are introduced (being placed at an angle of 25°) also connected with the blast apparatus and provided with regulating valves.

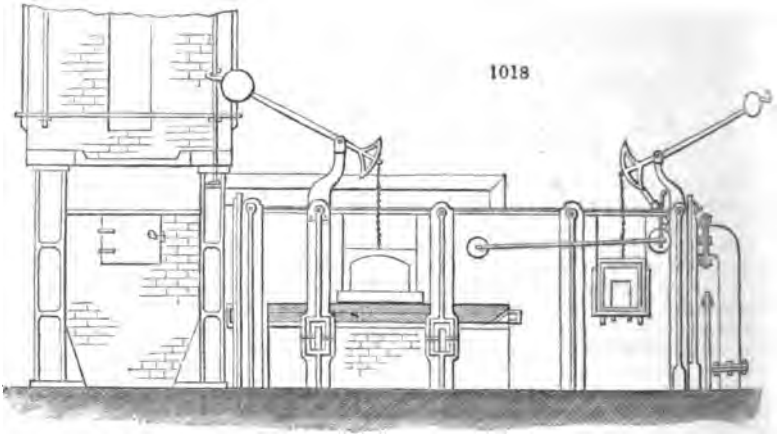
1016



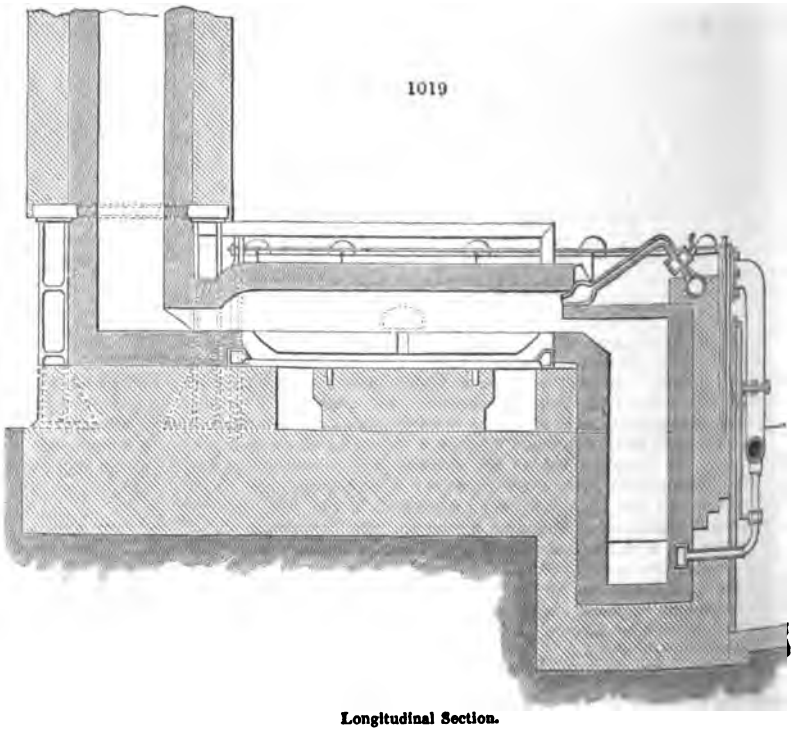
1017

The refining process is conducted as follows: — The hearth of the furnace having been constructed or repaired, a brisk coal-fire is kindled in the generator, through the opening at the bottom, which is afterwards bricked up. About 20 cubit feet of

coals are then introduced from above, and the necessary supply of air admitted to the generator through the lower air-chest. When these coals have been thoroughly ignited, the generator is filled with coals, and a very moderate supply of air admitted through the tuyères below (for the generation of the gas), and those over the bridge,



Eck's Gas Reverberatory Furnace. — Front view.

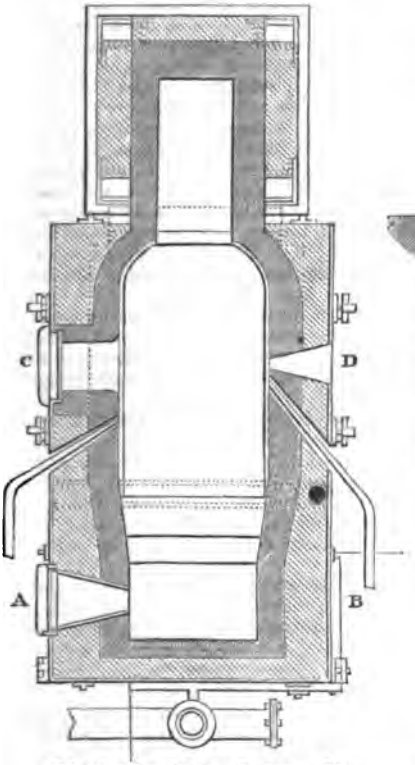


Longitudinal Section.

(for its combustion,) until the furnace is dried, when the supply of air at both places is increased, so as to raise the hearth to the temperature necessary for baking it thoroughly, upon which, about 40 cwt. of iron are introduced; the metal being distributed over the whole hearth as uniformly as possible, and the size of the pieces

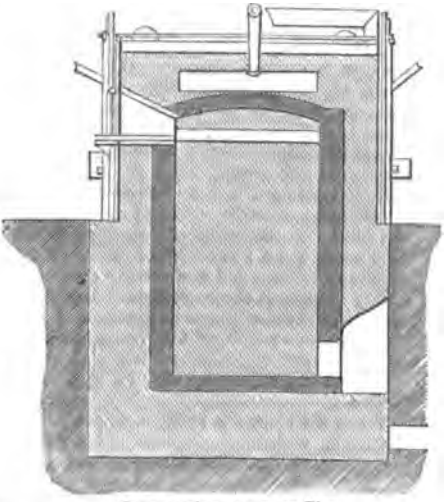
being selected with the view to expose as much surface as possible to the flame. The fusion of the charge of metal is effected in about three hours, the coal used amounting to about 3¾ cubic feet per hour. The gas generator is always kept filled

1020



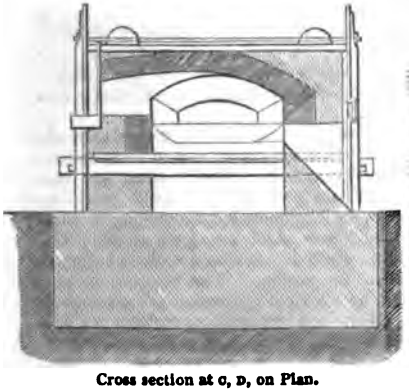
Eck's Gas Reverberatory Furnace. — Plan.

1021



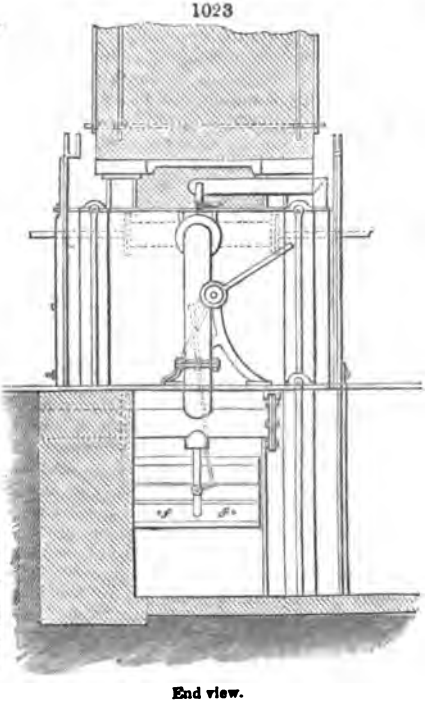
Cross section at A, B, on Plan.

1022



Cross section at C, D, on Plan.

1023



End view.

with coal, and the supply of air admitted from below is diminished by a regulation of the valve, whenever fresh coal is supplied, as the latter, at first, always yields gas more freely. The arrangement of the upper row of tuyères effects the combustion

of gases just as they pass from the generator on to the hearth. The hottest portion of the furnace is of course near the fire-bridge, *i. e.* where the blast first meets with the gases. During the melting process the iron is shifted occasionally, so that the cooler portion near the flue may in its turn become melted without loss of time. When the iron is ascertained to be throughly fused, about 5 lbs. of crusted limestone are thrown over its surface for the purpose of converting the dross which has separated into fusible slag. The two side tuyères are now introduced into the furnaces through the openings above alluded to, the width of the nozzle employed depending upon the power of the blast used. The air rushing from these tuyères impinges with violence upon the iron, and the two currents meeting an eddying motion is imparted to the fused metal. In a short time the motion produced in the mass is considerable; the supernatant slag is blown aside by the blast, and the surface of the iron thus exposed undergoes refinement, while it changes continually, the temperature of the whole mass being raised to a full white heat, by the action of the air. The iron is stirred occasionally, in order to insure a proper change in the metal exposed to the action of the blast. A shovelful of limestone is occasionally thrown in (the total quantity used being about 1 per cent. of the crude-iron employed). The slag produced is exceedingly fusible, and is allowed to remain in the furnace until the metal is tapped, and on cooling it separates from it completely.

The duration of the treatment in this furnace after the metal is fused, varies from two hours and a half to five hours, according to the product to be obtained. For the preparation of perfectly white iron, the treatment is carried on for five hours. A sample is tapped to examine its appearance, when it is believed to be sufficiently treated.

When the charge is to be withdrawn from the furnace, the side tuyère nearest the taphole is withdrawn, so that the blast from the opposite tuyère may force the metal towards the hole. The fluid iron, as it flows from the taphole is fully white hot, and perfectly limpid; it chills, however, very rapidly, and soon solidifies. A few pails of water are thrown upon those portions of the metal which are not covered with the slag, which flows out of the furnace, the object being to cool it rapidly, and thus prevent the oxidation of any quantity of iron. The loss of metal during the treatment is said not to exceed 5 per cent.

With regard to the purification which the iron undergoes in the gas reverberatory furnace, it appears to be confined chiefly to the elimination of carbon and silicium, the amount of sulphur and phosphorus undergoing but little alteration, as appears from the following analysis (*Abel*): —

	Pig iron.	Refined iron.
Silicium - - -	4·66	0·62
Phosphorus - -	0·56	0·50
Sulphur - - -	0·04	0·03

Nevertheless the iron thus refined is highly esteemed for all castings which are required to possess unusual powers of resistance: some experiments made to ascertain the comparative strain borne by the refined metal, and the same metal as obtained from the blast furnace, showed the strength of the former to be greater by one half than that of the latter.

The operation of puddling.—In the year 1783 and 1784, Mr. Henry Cort of Gosport obtained two patents, one for the puddling, and the other for the rolling of iron, "discoveries," says Mr. Scrivenor, "of so much importance in the manufacture, that it must be considered the era from which we may date the present extensive and flourishing state of the iron trade of this country."

The object of Mr. Cort's processes was to convert into malleable iron, cast or pig iron, by means of the flame of pit-coal in a common air furnace, and to form the result into bar by the use of rollers in the place of hammers. The process was managed in the following manner: — "The pigs of cast iron produced by the smelting furnace are broken into pieces, and are mixed in such proportions according to their degree of carbonisation, that the result of the whole shall be a grey metal. The mixture is then speedily run into a blast furnace, where it remains a sufficient time to allow the greater part of the scoriæ to rise to the surface. The furnace is now tapped, and the metal runs into moulds of sand, by which it is formed into pigs, about half the size of those which are broken into pieces. A common reverberatory furnace heated by coal is now charged with about 2½ cwt. of this half refined grey iron. In a little more than half an hour, the metal will be found to be nearly melted; at this period the flame is turned off, a little water is sprinkled over it, and a workman, by introducing an iron bar through a hole in the side of the furnace, begins to stir the half fluid mass, and divide it into small pieces. In the course of about 50 minutes from the commencement of the process, the iron will have been reduced by constant

stirring to the consistence of small gravel, and will be considerably cooled. The flame is then turned on again, the workmen continuing to stir the metal, and in three minutes' time the whole mass becomes soft and semifluid, upon which the flame is then turned off. The hottest part of the iron now begins to heave and swell, and emit a deep lambent blue flame, which appearance is called *fermentation*; the heaving motion and accompanying flame soon spread over the whole, and the heat of the metal seems to be rather increased than diminished for the next quarter of an hour; after this period the temperature again falls, the blue flame is less vigorous, and in a little more than a quarter of an hour the metal is cooled to a dull red, and the jets of flame are rare and faint. During the whole of the fermentation the stirring is continued, by which the iron is at length brought to the consistency of sand; it also approaches nearer to the malleable state, and in consequence adheres less than at first to the tool with which it is stirred. During the next half hour the flame is turned off and on several times, a stronger fermentation takes place, the lambent flame also becomes of a clearer and lighter blue; the metal begins to clot, and becomes much less fusible and more tenacious than at first. The fermentation then by degrees subsides; the emission of blue flame nearly ceases; the iron is gathered into lumps and beaten with a heavy-headed tool. Finally, the tools are withdrawn, the apertures through which they were worked are closed, and the flame is again turned on in full force for six or eight minutes. The pieces being thus brought to a high welding heat are withdrawn and shingled; after this they are again heated and passed through grooved rollers, by which the scoriæ are separated, and the bars thus forcibly compressed acquire a high degree of tenacity." But this mode of refining did not produce altogether the desired result. It was irregular; sometimes the loss of iron was small, but at others it was very considerable, and there were great variations in the quality of the iron, as well as in the quantity of fuel consumed. These difficulties were, however, removed by the introduction of the coke finery by the late Mr. Samuel Homfray, of Penydarran, upon which the puddling and balling furnaces came immediately into general use, with the addition of rollers in lieu of hammers.

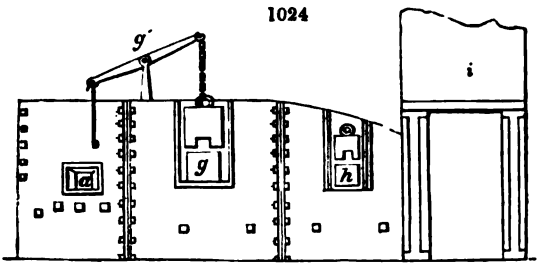
Mr. Cort's first patent, which is for "rolling," is dated 17th January, 1783; his second, that for "puddling," is dated 13th February, 1784. It has been attempted, though we think very unjustly, to detract from Cort's merits as an original inventor, by referring to the patents of John Payne, and Peter Onions, dated respectively 21st November, 1728, and 7th May, 1783. The first was to a certain extent, undoubtedly, a patent for "rolling;" for the bars rendered malleable by a process indicated, are "*to pass between the large metall rowlers which have proper notches or furrows upon their surface:*" but there is no proof that any practical use was made of Payne's process, while that of Cort was almost immediately and universally adopted: it may be true therefore that Cort was the *rediscoverer* and not the actual *discoverer* of the process of rolling, but this in no way detracts from his merit, inasmuch as by his improvements, he was enabled to make available that which was previously useless. The same observation applies to the patent of Onions, which to a certain extent anticipated that of Cort for puddling. Onions employed two furnaces—a common smelting furnace, and a furnace of stone and brick, bound with iron work and well annealed, into which the fluid metal was received from the smelting furnace. When the liquid metal had been introduced into the second furnace by an aperture, it was closed up and subjected to the heat of fuel and blast from below, until the metal became less fluid, and thickened into a kind of paste; this the workman by opening a door turns and stirs with a bar of iron, and then closes the aperture again, after which blast and fire is applied until there is a *ferment* in the metal; the adherent particles of iron are collected into a mass, reheated to a white heat, and forged into malleable iron. That the process of puddling is here indicated there can be no doubt, but the actual operation was impracticable until Henry Cort invented the *furnace* in which it could be conducted.

Neither Mr. Cort nor his family appear to have derived much advantage from his important discoveries—discoveries which changed us at once from dependent importers of iron into vast exporters to every country of the world, and which may be considered to have founded the iron industry of Great Britain. So long ago as 1811, the chief representatives of the trade assembled at Gloucester unanimously acknowledged their indebtedness to Mr. Cort for the improvements of which he was the author, and this acknowledgment has been repeated within the last twelvemonths by *Robert Stephenson, Fairbairn, Maudslay and Field, Cubitt, Rendel, Sir Charles Fox, Bidder, Crawshay, Bailey,* and many others. In working out his inventions, Cort is said to have expended a fortune of 20,000*l.*, and when his patents were completed, the leading iron masters of the country contracted to pay him 10*s.* a ton for their use, so that he would not only have been repaid, but munificently rewarded, had he not unfortunately connected himself with a man named Adam Sellicoe, chief clerk of the Navy Pay Office, who

proving to be a defaulter, committed suicide, having previously destroyed the patents and the agreements with ironmasters belonging to his partner, Henry Cort. Upon the death of Sellicoe, the premises, stock, and entire effects of Cort were sold by a summary process obtained by the Navy Pay Office, and the unfortunate man was thus completely ruined.

The *puddling furnace* is of the reverberatory form. It is bound generally with iron, as represented in the side view, *fig.* 1024, by means of horizontal and vertical bars,

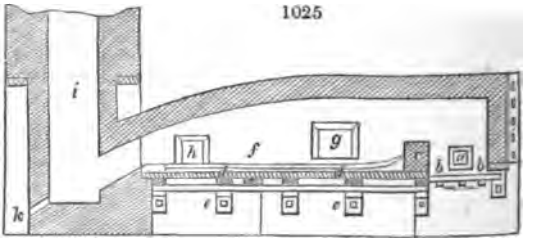
1024



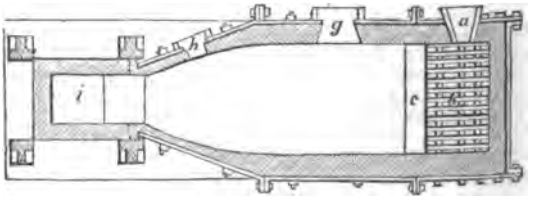
which are joined together and fixed by wedges, to prevent them from starting asunder. Very frequently, indeed, the reverberatory furnaces are armed with cast iron plates over their whole surface. These are retained by upright bars of cast iron applied to the side walls, and by horizontal bars of iron, placed across the arch or roof. The furnace itself is divided interiorly into three parts; the *fireplace*, the *hearth*, and the *flue*. The *fireplace* varies from 3½ to 4½ feet long, by from 2 feet 8 inches to 3 feet 4 inches wide. The door-way, by which the coke is charged, is 8 inches square, and is bevelled off towards the outside of the furnace. This opening consists entirely of cast iron, and has a quantity of coal gathered round it. The bars of the fire grate are movable, to admit of more readily clearing them from ashes.

Fig. 1025 is a longitudinal section referring to the elevation, *fig.* 1024, and *fig.* 1026

1025



1026

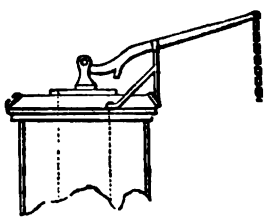


is a ground plan. When the furnace is a single one, a square hole is left in the side of the fireplace opposite to the door, through which the rakes are introduced, in order to be heated.

a is the fire-door; *b*, the grate; *c*, the fire-bridge; *d d*, cast iron hearth-plates, resting upon cast iron beams *e e*, which are bolted upon both sides to the cast iron binding plates of the furnace. *f* is the hearth covered with cinders or sand; *g*, is the main working door, which may be opened and shut by means of a lever *g'*, and chain to move it up and down. In this large door there is a hole 5 inches square, through which the iron may be worked with the paddles or rakes; it may also be closed air-tight. There is a second working door *h*, near the flue, for introducing the cast iron,

so that it may soften slowly, till it be ready for drawing towards the bridge. *i*, is the chimney, from 30 to 50 feet high, which receives commonly the flues of two furnaces, each provided with a damper plate or *register*. *Fig.* 1027, shows the main damper for the top of the common chimney, which may be opened or shut to any degree by means of the lever and chain. *k*, *fig.* 1025, is the tap or floss hole for running off the slag or cinder.

1027



The sole is sometimes made of bricks, sometimes of cast iron. In the first case it is composed of fire-bricks set on edge, forming a species of flat vault. It rests immediately on a body of brickwork either solid or arched below. When it is made of cast iron, which is now beginning to be the general practice, it may be made either of one piece or of several. It is commonly in a single piece, which, however, causes the inconvenience of reconstructing the furnace entirely when the sole is to be changed. In this case it is a little hollow, as is shown in the preceding vertical section; but if it consists of several pieces, it is usually made flat.

The hearths of cast iron rest upon cast iron pillars, to the number of four or five; which are supported on pedestals of cast iron placed on large blocks of stone. Such an arrangement is shown in the figure, where also the square hole *a*, *fig.* 1025, for heating the rake irons, may be observed. The length of the hearth is usually 6 feet; and its breadth varies from one part to another. Its greatest breadth, which is opposite the door, is 4 feet. In the furnace, whose horizontal plan is given above, and which produces good results, the sole exhibits in this part a species of ear, which enters into the mouth of the door. At its origin towards the fireplace, it is 2 feet 10 inches wide; from the fire it is separated, moreover, by a low wall of bricks (the fire bridge) 10 inches thick, and from 3 inches to 5 high. At the other extremity its breadth is 2 feet. The curvature presented by the sides of the sole or hearth is not symmetrical; for sometimes it makes an advancement, as is observable in the plan. At the extremity of the sole furthest from the fire, there is a low rising in the bricks of 2½ inches, called the altar, for preventing the metal from running out at the *floss hole* when it begins to fuse. Beyond this shelf the sole terminates in an inclined plane, which leads to the *floss*, or outlet of the slag from the furnace. This *floss* is a little below the level of the sole, and hollowed out of the basement of the chimney. The slag is prevented from concreting here, by the flame being made to pass over it, in its way to the sunk entry of the chimney; and there is also a plate of cast iron near this opening, on which a moderate fire is kept up to preserve the fluidity of the scoriæ, and to burn the gases that escape from the furnace, as also to quicken the draught, and to keep the remote end of the furnace warm. On the top of this iron plate, and at the bottom of the inclined plane, the cinder accumulates in a small cavity, whence it afterwards flows away; whenever it tends to congeal, the workman must clear it out with his rake.

The door is a cast iron frame filled up inside with fire-bricks; through a small hole in its bottom the workmen can observe the state of the furnace. This hole is at other times shut with a stopper. The chimney has an area of from 14 to 16 inches.

The hearth stands 3 feet above the ground. Its arched roof, only one brick thick, is raised 2 feet above the fire bridge, and above the level of the sole, taken at the middle of the furnace. At its extreme point near the chimney, its elevation is only 8 inches; and the same height is given to the opening of the chimney. The sole is covered with a layer of finely pounded cinders from previous workings mixed with mill cinders; formerly the bottoms were of sand, by which great loss of iron was occasioned, and the metal obtained of inferior quality.

The fine metal obtained by the coke is *puddled* by a continuous operation, which calls for much care and skill on the part of the workmen. To charge the puddling furnace, pieces of *fine metal* are successively introduced with a shovel, and laid one over another on the sides of the hearth, in the form of piles rising to the roof; the middle being left open for puddling the metal, as it is successively fused. Indeed, the whole are kept as far separate as possible, to give free circulation to the air round the piles. The working door of the furnace is now closed, fuel is laid on the grate, and the mouth of the fireplace, as well as the side opening of the grate, are both filled up with coal, at the same time that the damper is entirely opened.

The fine metal in about twenty minutes comes to a white-red heat, and its thin edged fragments begin to melt and fall in drops on the sole of the furnace. At this period the workman opens the small hole of the furnace door, detaches with a rake the pieces of fine metal that begin to melt, tries to expose new surfaces to the action of the heat, and in order to prevent the metal from running together as it softens, he

removes it from the vicinity of the fire bridge. When the whole of the fine metal has thus got reduced to a pasty condition, he must lower the temperature of the furnace to prevent it from becoming more fluid. He then works about with his paddle the clotty metal which swells up, exhibiting a kind of fermentation occasioned by the discharge of carbonic oxide, burning with a blue flame as if the bath were on fire. The metal becomes finer by degrees and less fusible, or, in the language of the workmen, it begins to *dry*. The disengagement of carbonic oxide diminishes and soon stops. The workman continues meanwhile to puddle the metal till the whole charge is reduced to the state of incoherent sand; the register is then progressively opened. With the return of heat the particles of metal begin to agglutinate, the charge becomes more difficult to raise, or, in the labourer's language, it *works heavy*. The refining is now finished, and nothing remains but to gather the iron into balls. The puddler with his paddle takes now a little lump of metal as a nucleus, and makes it roll about on the surface of the furnace, so as to collect more metal, and form a ball of about 60 or 70 lbs. weight. With a kind of rake called in England a *dolly*, and which he heats beforehand, the workman sets this ball on that side of the furnace most exposed to the action of the heat in order to unite its different particles, which he then squeezes together to force out the scoriæ. When all the balls are fashioned, the small opening of the working door is closed with brick to cause the heat to rise, and to facilitate the welding. Each ball is then lifted out either with the tongs, if roughing rollers are to be used, as in Wales, or with an iron rod welded to the lump as a handle, if the hammer is to be employed, as in Staffordshire. It is usual to introduce a fresh charge when the portion under operation has arrived at the pasty condition; when this is done, the entire process is effected in about 1½ hour.

The charge for each operation is from 4 cwts. to 4¾ cwts. of refined metal, and sometimes the cuttings of bar ends are introduced, which are puddled apart. The loss of iron is here very variable, according to the degree of skill in the workman, who by negligence may suffer a considerable body of iron to scorify or to flow into the hearth and raise the bottom. Taking the average of 85 furnaces for 22 years' working Mr. Truran finds the consumption of refined metal to produce one ton of puddle bars to be 21 cwt. 1 qr. 20 lbs. The consumption of coal is likewise subject to variation. With coal of good quality, and suitable for reverberatory furnaces, the ton of puddled bars is produced with a consumption of from 12 to 15 cwt.; but, if the coal be of the anthracitic character, from 18 cwt. to 1 ton will be required. About five puddling furnaces are required for the service of one smelting furnace and one refinery. Each furnace, with good workmen, turns out about 23 tons of puddled bars weekly.

The cast iron bottom and sides of the puddling furnace are kept cool by currents of air, or, in those portions exposed to the greatest heat, by water. The cinders of the charcoal finery are much esteemed for lining the bottom. When melted into one uniform mass, with the addition of oxide of iron, these scoriæ form a bottom offering great resistance to the action of the melted metal.

Various patents have been taken out within the last four or five years for the employment of chemical agents to assist in the purification of iron in the puddling furnace: some of these have already been alluded to. One of the latest is that of M. Charles Pauvert of Chatellerault, who proposes to employ a cement composed of the following substances: — oxide of iron, 14 parts; highly aluminous clay, 30 parts; carbonate of potash, 1 part; carbonate of soda, 1 part. The iron is to be placed with the cement in layers, and heated in the furnace in the ordinary manner. After cementation it is welded, and then drawn into bars; it is stated to become thus as soft and tenacious as iron made from charcoal. Schafhæult's compound, for which a patent was secured in 1835, is said by Overmann to furnish very satisfactory results, and where competent workmen are employed, a good furnace is said to make a heat in two hours, producing neither too much nor too little cinder in the furnace. The compound consists of common salt, 5 parts; oxide of manganese, 3 parts; fine white plastic clay, 2 parts. The pig is heated as in common operations. It is melted down by a rapid heat, the damper is closed, and the cinder and metal diligently stirred. In the meantime the above mixture, in small parcels of about half a pound, is introduced in the proportion of one per cent. of the iron employed; if, after this, the cinder does not rise, a hammer slag (rolling mill cinder) may be applied.

The "Boiling" process.— In this operation, which was the invention of Mr. Joseph Hall, pig iron is converted into malleable iron without the intervention of the refinery, and without any excessive waste: it is, therefore, of great value, especially as it allows of the use of better qualities of pig iron than those usually employed. The construction of the "boiling" furnace does not materially differ from that of the "puddling" furnace, except in the depth of the hearth, that is, in the distance from the work plate below the door to the bottom plate, which, in the former, is double, or

nearly so, that of the latter. In the puddling furnace the distance between the bottom and top seldom exceeds twenty inches, while in the boiling furnace it varies from twenty to thirty. In *puddling* the furnace is charged with metal alone, but in boiling *cinder* is charged along with the metal, and the temperature rises much higher. The bottom of the furnace is covered with broken cinders from previous workings, or with the tap cinder from the puddling furnace, which has been subjected to a process of calcination in kilns; this material, which constitutes an admirable protection to the iron plates of the furnace, is called by the workmen "bull dog;" its preparation was patented by Mr. Hall in 1839. It is made in the following manner: the tap cinder from the puddling furnace is placed in layers in a kiln, and so arranged that a draught shall pass through from the fire holes on one side to those on the other; the kiln is filled up to the top with broken cinders, and over the whole is laid a layer of coke; about the third or fourth day, the more fusible part of the cinder begins to run out of the bottom holes, leaving in the kiln a fine rich porous silicate of iron, which is the substance used for lining the boiling furnace, the fluid portion being rejected. In 8 or 10 hours the "bull dog" is melted by the intense heat of the furnace, covering the bottom, and filling up all the interstices in the brickwork; the heat is now somewhat lowered by diminishing the draught, and the charge of pig (from 3½ to 4½ cwts.) introduced in fragments of a convenient and uniform size, together with 30 or 40 lbs. of cinder; the doors of the furnace are now closed, and all access of cold atmospheric air prevented, throwing fine cinder or hammer slag round the crevices, and stopping up the work hole with a piece of coal. In about a quarter of an hour the iron begins to get red-hot; the workman then shifts the pieces so as to bring the whole to a state of uniformity as regards heat. In about half an hour the iron begins to melt; it is constantly turned over, and at intervals of a few minutes cinder is thrown in; the surface of the mass is seen to be covered with a blue flame; it soon begins to rise; a kind of fermentation takes place beneath the surface, and the mass, at first but 2 inches high, rises to a height of 10 or 12 inches, and enters into violent ebullition. During the time that this "fermentation" is taking place, constant stirring is required to prevent the iron from settling on the bottom. The *boiling* lasts about a quarter of an hour; after which the cinder gradually sinks, and the iron appears in the form of porous spongy masses of irregular size, which are constantly stirred to prevent their adhering together in large lumps, to facilitate the escape of the carbon, and to separate the cinder which, when the operation has been successfully conducted, flows over the bottom apparently as liquid as water. The iron is now "balled up," as in the operation of puddling. The objections to the boiling process are: the wear and tear in the furnace which occurs in treating grey pig iron, particularly that of the more fluid description; the slowness of the operation, and the amount of manual labour which it entails to produce good results. In some works the crude iron is run directly into the boiling furnace from the blast furnace, by which much saving of coal is effected, and a product of a more uniform quality obtained; but the labour of the workman becomes more oppressive from the additional heat to which he is subjected from the close proximity of the blast furnace. Ironmasters are not agreed as to the respective merits of the "boiling" and "puddling" systems; some maintain that the former is more economical than the latter, which involves "refining;" others think that boiling iron has a tendency to communicate to it the "red short" quality. According to the observations of Mr. Truran, in several works where both methods are employed, the largest quantity of iron is first passed through the refinery.

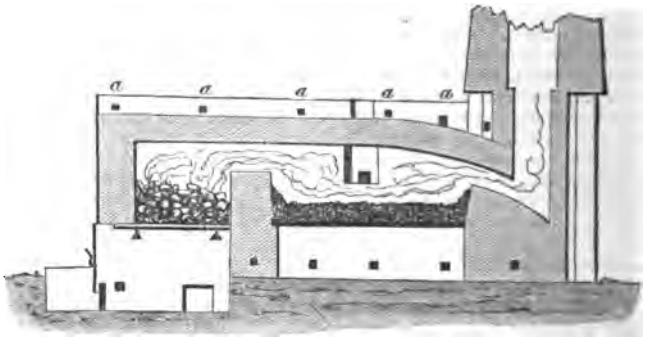
Mr. Hall, the inventor of the boiling system, in descanting on the merits of his process, describes how, with the same pig, the iron may be made weak and cold short; or tough, ductile, and malleable. For the first proceed thus: — Pass the pig through the refinery, then puddle agreeably to the old plan on the sand bottom; that is, melt it as cold as possible; drop the damper quite close before the iron is all melted, dry the iron as expeditiously as may be, with a large quantity of water; and, lastly, proceed to ball in a proper number of "young" balls; the result will be a very inferior quality of manufactured iron. On the other hand, to produce a malleable iron of very superior quality, first charge the furnace with good forge pig iron, adding, if required, a sufficiency of flux, increasing or diminishing the same in proportion to the quality and nature of the pig iron used. Secondly, melt the iron to a boiling consistency. Thirdly, clear the iron thoroughly before dropping down the damper. Fourthly, keep a plentiful supply of fire upon the grate. Fifthly, regulate the draft of the furnace by the damper. Sixthly, work the iron into one mass, before it is divided into balls; when thus in balls, take the whole to the hammer as quickly as possible, after which roll the same into bars. The bars being cut into lengths, and piled to the desired weights, are then heated in the mill furnace, welded and compressed by passing through the rolls, and thus finished for the market. In this way, from the pig to the finished mill bar, one entire process, that of the refinery, is saved. Mr. Hall

states that, by his process, he can obtain malleable iron of any character (premising that the ores from which the pig is smelted are of good quality), from the softness of lead to the hardness of steel, and further that he can exhibit different qualities in the same bar, one end being crystalline, nearly as brittle as glass, the other end equal to the best iron that can be produced for fibre and tenacity, while the middle exhibits a character approximating to both; and as a further illustration of the excellence of the iron that may be made by the "pig boiling" process, he refers to a specimen in the Geological Museum, Jermyn Street, London, labelled "Specimen of two and a quarter inch round iron, tied cold, manufactured at the Bloomfield Iron Works, Tipton, Staffordshire." This specimen has been called a "Staffordshire knot," it was made from a bar two inches and a quarter in diameter, and nearly seven inches in circumference; also to a "Punched Bar," half inch thick, made at one process for the smithy, commencing with a half inch punch, and terminating with one six and a half, without exhibiting the slightest fracture.

Mr. Hall was led to the discovery of the "boiling" principle, by noticing the exceedingly high fusion which took place on subjecting puddling furnace slag to a high degree of heat, and the excellence of the bloom of iron produced by the operation: it occurred to him, that if such good iron could be made from cinder alone, a very superior product ought to be obtained from good pig iron, with equally good fluxes, and the result of experiments fully answered his expectation, though for a long time he was unable to make his discovery practically useful, on account of the difficulty of getting furnaces constructed capable of rendering the intense heat required and the corroding action of the fluxes. Puddling furnaces were then made of brick and clay, with sand bottoms. He succeeded at last by lining the interior of the furnace with iron, and protecting them with a coating of prepared tap cinders.

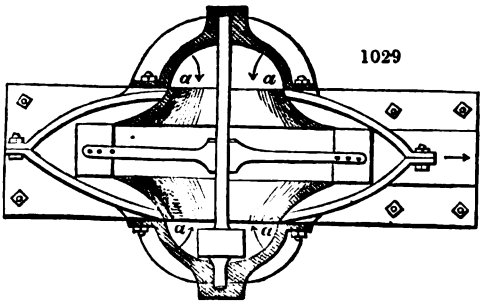
In America, the "puddling" and "boiling" processes are both in use. Overman gives preference to the latter as being the most profitable, but it can only be employed to a limited extent for lack of cinder; in a rolling mill forge, therefore, half

1028



the furnaces are employed for boiling, and half for puddling, the latter supplying cinder for the former. In the eastern states where the fuel is anthracite, double puddling furnaces are employed and a blast is used, the incombustibility of this variety of coal rendering it impossible to get the requisite heat by merely the draught of the chimney. *Fig.* 1028 represents an anthracite furnace bisected vertically through the grate, hearth, and chimney. It differs from the ordinary puddling furnace chiefly in the greater depth of the grate, which is made to contain from twenty to twenty-four inches of coal, and in the lesser height of the chimney, which, as a blast is employed, need only be sufficiently high to carry the hot gases out of the furnace; the letters *a*, *a*, *a*, *a*, *a*, indicate the position of the iron cross binders, which serve to bind together the

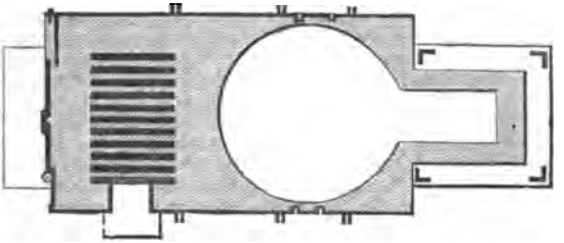
1029



cast iron plates of the enclosure, and to prevent the sinking of the roof from the expansion and contraction of the brickwork.

The blast machines are fans, the best form of which is shown in *fig.* 1029. (*Overman.*) The wings of this fan are encased in a separate box; a wheel is thus formed, which rotates in the outer box, the figure shows a horizontal section through the axis. The wings are thus connected, and form a closed wheel, in which the air is whirled round, and thrown out at the periphery. The inner case, which revolves with the wings, is fitted as closely as possible to the outer case, at the centre near *a*, *a*, *a*, *a*. The speed of the wings is sometimes as much as 1800 revolutions per minute. The motion of the axis is produced by means of a leather or india-rubber belt and a pulley. This variety of fan is used at the puddling furnaces at Ebbw vale, where the fuel is small coal.

Fig. 1030 is a horizontal section of the double anthracite puddling furnace. The



1030

grate measures 3 feet by 5. The width of the furnace externally is from 5½ to 6 feet. The hearth is usually 6 feet in length It has two work doors, one directly opposite the other. Two sets of workmen are required therefore at the same time; double the quantity of metal is charged, and the yield is twice that of a single furnace; the economy is in the room, fuel, and labour; one good puddler only being required to manage the operation. Double puddling furnaces are also used in several works in England, but as Mr. Truran observes, the economical advantages attending them in point of fuel are lost if the puddlers do not work well to time: they must bring their heats to the respective stages simultaneously, for if one is kept waiting for a short period by the other, the loss in iron more than balances the reduced consumption of coal. This difficulty of obtaining men who will work well in concert has operated against the use of the double furnace, which would otherwise certainly supersede the single, as combined with the process of running the iron in liquid from the blast furnace, the consumption of fuel is under the one half of the quantity demanded with single furnaces working cold iron.

Puddling furnaces are sometimes constructed with what is called "water boshes." the hearth is surrounded with heavy cast iron plates, in which is formed a passage of an inch or an inch and a half bore, through which a current of cold water is caused to flow, the object being to protect the furnace from the destructive action of the heat and cinder. Overman found such furnaces to work well with fusible metal such as is produced from a heavy burden on the blast furnace, or from ores containing phosphorus; but with iron requiring a strong heat, such as results from a light burden on the blast furnace, or when it contains impurities firmly and intimately combined, puddling furnaces with cooled boshes failed to make good malleable iron.

We do not know whether the iron manufacturers in England will assent to the following proposition laid down by the American metallurgist, viz. "That the smaller the amount of coal consumed, or the lower the temperature of the hearth in the blast furnace, the better will be the quality of the metal; that is, the more fit it will become for improvement in the puddling furnace. The advantage of heavy burden in the blast furnace, is not only that it reduces the first cost of the metal, but makes a far superior article for subsequent operations. The worst cold short, or sulphurous metal, smelted by a low heat is quite as good as the best metal from the best ore smelted by a high temperature." Whatever may be thought of the latter part of this quotation, no iron manufacturer will deny that careful attention to the blast furnace is the best security of success in the puddling furnace, and that success in the one is in proportion to the economy observed in relation to the other; or that it is hopeless to attempt to improve in the puddling furnace pig iron made in a furnace that is constantly changing its burden and management; such iron is most advantageously disposed of by being worked up into coarse bar or railroad iron.

In the autumn of 1856 the attention of ironmasters and of the public generally was powerfully excited by a proposal from Mr. Bessemer to manufacture iron and steel

from crude iron, without any fuel at all. The views of Mr. Bessemer were first communicated to the public in a paper read by that gentlemen at the meeting of the British Association held at Cheltenham in August; from this paper the following extracts are taken, descriptive of the apparatus employed, and of the phenomena attending the conversion.

"The furnace is a cylindrical vessel of three feet in height, somewhat like an ordinary cupola furnace, the interior of which is lined with fire bricks; and at about two inches from the bottom are inserted fire tuyère pipes, the nozzles of which are formed of well burnt fire clay, the orifice of each tuyère pipe being about three eights of an inch in diameter. These are so put into the brick lining (from the outer side), as to admit of their removal or renewal in a few minutes when they are worn out. At one side of the vessel, about half way up from the bottom, there is a hole made for running in the crude metal; and on the opposite side a tap hole stopped with loam, by means of which the iron is run out at the end of the process. The vessel is placed so near the discharge hole of the blast furnace as to allow the iron to flow along a gutter into it. A small brass cylinder is required, capable of compressing air to about 8 lbs. or 10 lbs. to the square inch. A communication having been made between it and the tuyères, the converting vessel is in a condition to commence work. Previous, however, to using the cupola for the first time, it must be well dried by lighting a fire in the interior. The tuyères are situated nearly close to the bottom of the vessel, the fluid metal rises, therefore, some 18 inches or two feet above them. It is necessary, in order to prevent the metal from entering the tuyère holes, to turn on the blast before allowing the crude iron to run into the vessel from the blast furnace. This having been done, and the fluid iron run in, a rapid boiling up of the metal is heard going on within the vessel, the metal being tossed violently about, and dashed from side to side, shaking the vessel by the force with which it moves from the throat of the converting vessel. Flame will then immediately issue, accompanied by a few bright sparks. This state of things will continue for about 15 or 20 minutes, during which time the oxygen of the atmospheric air combines with the carbon contained in the iron, producing carbonic acid gas, and at the same time evolving a powerful heat. Now as this heat is generated in the interior of, and is diffused in innumerable fiery bubbles through, the whole fluid mass, the metal absorbs the greater part of it, and its temperature becomes immensely increased, and by the expiration of 15 or 20 minutes, the mechanically mixed carbon or graphite has been entirely consumed. The temperature is, however, so high that the chemically combined carbon, now begins to separate from the metal, as is at once indicated by an immense increase in the volume of the flame rushing out at the throat of the vessel. The metal now rises several inches above its natural level, and a light frosty slag makes its appearance, and is thrown out in large foam-like masses. This violent eruption of cinder generally lasts 5 or 6 minutes, replacing the shower of sparks and cinder which always accompanies the boil.

"The rapid union of carbon and oxygen which thus takes place, adds still further to the temperature of the metal, while the diminished quantity of carbon present, allows a part of the oxygen to combine with the iron, which undergoes combustion, and is converted into oxide, at the excessive temperature that the metal has now acquired; the oxide, as soon as it is formed, undergoes fusion, and forms a powerful solvent of those earthy bases that are associated with the iron. The violent ebullition which goes on mixes most intimately the scoriæ and metal, every part of which is brought into contact with the fluid, which will thus wash and cleanse the metal most thoroughly from the silica and other earthy bases, while the sulphur and other volatile matters which cling so tenaciously to iron at ordinary temperatures, are drawn off, the sulphur combining with the oxygen and forming sulphurous acid gas. The loss in weight of crude iron during its conversion into an ingot of malleable iron was found on a mean of four experiments to be 12½ per cent., to which will have to be added the loss of metal in the finishing rolls. This will make the entire loss probably not less than 18 per cent., instead of about 28 per cent., which is the loss on the present system. A large portion of that metal is, however, recoverable, by treating with carbonaceous gases the rich oxides thrown out of the furnace during the boil. These slags are found to contain innumerable small grains of metallic iron, which are mechanically held in suspension in the slags, and may be easily recovered by opening the tap hole of the converting vessel, and allowing the fluid malleable iron to flow into the iron ingot moulds placed there to receive them.

"The masses of iron thus formed will be perfectly free from any admixture of cinder, oxide, or any other extraneous matters, and will be far more pure and in a sounder state of manufacture than a pile formed of ordinary puddled bars. And thus it will be seen that by a single process, requiring no manipulation or particular skill, and with only one workman, from 3 to 5 tons of crude iron passes into the condition of

several piles of malleable iron in from 30 to 35 minutes, with the expenditure of about ⅛ of the blast now used in a finery furnace with an equal charge of iron, and with the consumption of no other fuel than is contained in the crude iron. . . .

"One of the most important facts connected with this new system of manufacturing malleable iron, is that all the iron so prepared will be of that quality known as *charcoal iron*, because the whole of the processes being conducted without the use of mineral fuel, the iron will be free from those injurious properties which that description of fuel never fails to impart to iron that is brought under its influence.

"At that stage of the process immediately following the boil the whole of the crude iron has passed into the condition of *cast steel* of ordinary quality. By the continuation of the process the steel so produced gradually loses its small remaining portion of carbon, and passes successively from hard to soft steel, and from soft steel to steely iron, and eventually to very soft iron; hence at a certain period of the process any quality of metal can be obtained."

The phenomena attending this novel process of iron making are very well described in the above extract, and if we substitute for the words "a few bright sparks," the words "showers of bright sparks, poured out in enormous quantities, projected thirty or forty feet into the air, and falling on all sides in a thick shower," a good idea may be formed of the gorgeous display of pyrotechny which is exhibited. We must demur, however, to the statement that "the sulphur and other volatile matters present in the crude iron are drawn off;" the fact being that the sulphur and phosphorus appear to have suffered little if any diminution, notwithstanding the excessive temperature and the powerful oxidising action to which the iron has been subjected. Thus Mr. Abel found, in a specimen of Mr. Bessemer's product from 0·4 to 0·5 per cent. of phosphorus, and from 0·05 to 0·06 per cent of sulphur; the Blaenarvon pig, from which it was stated to have been prepared, containing 0·5 of the former and 0·06 of the latter, and in a sample, broken off from an ingot cast at Baxter House, Sept. 1st, 1856, on which occasion we were present, and witnessed the whole process, we obtained 0·6 per cent. of phosphorus and 0·08 per cent. of sulphur; similar results have been obtained by other chemists. The carbon and silicon, on the other hand, are eliminated, the latter wholly so, while the quantity of the former is reduced to a few hundredths per cent.; we think also that Mr. Bessemer is mistaken in stating that the iron produced by his method contains "no admixture of oxide," for the specimens which we have had an opportunity of examining presented unmistakable evidence of partial oxidation in the very centre of the ingot, nor do we see how it could well be otherwise.

It will easily be imagined that a process which, if successful, must have revolutionised the whole iron manufacture, was speedily subjected to a most careful and sifting investigation; and, for some months after its announcement, the papers were filled with communications from all parts of the country, detailing experiments made on the large scale to test its value; the results, unfortunately for the ingenious projector, were unanimously unfavourable. We quote first from the "Mining Journal" of Nov. 29, 1856.

"The Dowlais Company appear to have thoroughly and impartially tested Mr. Bessemer's process, and the results obtained can only be regarded as a total failure. . . . . A Bessemer furnace was erected, and acted excellently as far as the process was concerned, but failed to produce anything like malleable iron. The iron used was from clay-ironstone, Whitehaven hæmatite, and small portions of forge cinders, in the proportions usually employed in Wales for rails and merchant iron. After the metal had been subjected to a blast of 8 lbs. pressure it was withdrawn and taken to the 'squeezer,' as is usual with puddled blooms, to take out the dross and unite the particles of metal. Instead of acting like puddled iron Mr. Bessemer's bloom under the squeezer was a mere mass of red-hot friable matter, and, from its crumbling and non-cohesion, was with difficulty formed into an ingot: when passed through the rolls it broke on the drawing side as easily as very 'red short' iron, to the infinite gratification of the men, who greeted each failure with hearty cheers. By mixing slag with the metal a slight improvement was effected, but, on being submitted to a similar manipulation, it was found to be no better than 'cold short' iron."

From the "Cambrian," 10th Jan. 1857: —

"On December 31st the Briton Ferry Iron Company received two of Bessemer's finest ingots of iron to test its value after passing through the rolls. Notwithstanding every care that was bestowed on the process, it was found impossible to do anything with it to the purpose, and the manager informs us that old *rekit* iron, after passing through the same process, is worth by at least 3*l.* per ton more than that tried on this occasion."

At a meeting of the Polytechnic Society at Liverpool, Monday, Sept. 16, 1856, the chairman, Edward Jones Eyre, is reported ("Daily News") to have said that a

specimen of Bessemer's iron had been received and tested by Mr. Clay in the presence of Mr. Dawson and himself, and, he regretted to say, had been far from satisfactory; the specimen submitted had all the appearance of *burned* and *imperfect cast iron*. He might say it was *rotten hot* and *rotten cold*. Mr. Dawson corroborated this statement, and also said that he had been much disappointed in the result; the portion submitted to the rolling machine had proved in every way *intractable*. The chairman added that he hoped ere long better results would be obtained; but in the one to which he referred he was informed that the iron cost 6*l*. per ton originally, and after being operated on, as he saw it, he did not consider it worth 4*l*. per ton.

Lastly, we find in the "Mining Journal" of January 3rd, 1857, that the Bessemer process was tried at the works of Messrs. Jackson, near Glasgow. The usual appearances were noticed, and after about 40 minutes the furnace was tapped, and the purified iron ran white and limpid into moulds prepared for the purpose. After allowing it to cool it was examined; it had a bright silvery whiteness with large crystals, but was exceedingly brittle. When rolled it preserved the same crystalline appearance on fracture, but in a state of greater compression and without the slightest trace of fibre. It is stated to have been deficient in every quality which would render it valuable for such purposes as malleable iron is usually applied to—in fact, the specimens examined were not malleable, and had nothing of tenacity or ductility, properties which render iron valuable, and are so indispensable for the mechanical requirements of the present age.

Although, therefore, it is scarcely probable that fibrous iron will ever be made from metal that has been subjected to Bessemer's treatment, and although that gentleman was premature in announcing his invention as a thing proved to be practical, we are far from asserting, as some have done, that the time of iron masters has been needlessly occupied in experimenting on the subject, or that no good is likely to accrue to the iron manufacture from all that has been done and written thereon. The extraordinary tenacity with which iron retains sulphur and phosphorus has been exhibited, and the fact that we must resort to other oxidising agents than that of air to eliminate them has been demonstrated. The injurious effect of an excessive temperature on the body and quality of iron has been clearly manifested, and the opinions of those whose experience has taught them that it is vain to look for the production of a tough flexible bar from iron which has lost nearly the whole of its carbon, rapidly or without manipulation, has been confirmed. It is more than probable that iron containing only 0·05 per cent. of carbon has almost lost the property of becoming fibrous by any treatment; for without going so far as to assert that the development of fibre depends on the presence of carbon, or that carbon exercises a specific function in bringing about this molecular condition of the iron, analysis shows that the toughest and most flexible bar iron contains a far larger quantity of carbon than that above indicated, as will be seen by the following analyses by Gay-Lussac, Willson, Karsten, and Bromeis.

Amount of Carbon in Bar Iron.

	Carbon.
Best bar iron from Sweden	0·293
" "	0·240
Bar iron from Creusat	0·159
Bar iron from Champagne	0·193
Bar iron from Berry	0·162
Cold short bar iron from Moselle	0·144
Soft bar iron analysed by Karsten	0·200
Hard bar iron by Karsten	0·500
Three different varieties produced from white pig iron by the Swabian method of refining, analysed by Bromeis	0·318
Three different varieties produced from white pig iron by the Swabian method of refining, analysed by Bromeis	0·354
Three different varieties produced from white pig iron by the Swabian method of refining, analysed by Bromeis	0·40
Three varieties produced from various kinds of pig iron by the Mägdesprung method of refining	0·324
Three varieties produced from various kinds of pig iron by the Mägdesprung method of refining	0·497
Three varieties produced from various kinds of pig iron by the Mägdesprung method of refining	0·66

It will be noticed that the smallest amount of carbon indicated in these analyses is nearly three times greater than that found in Bessemerised iron, and in this specimen the iron is stated to be "cold short" which means deficient in fibre; it is probable that

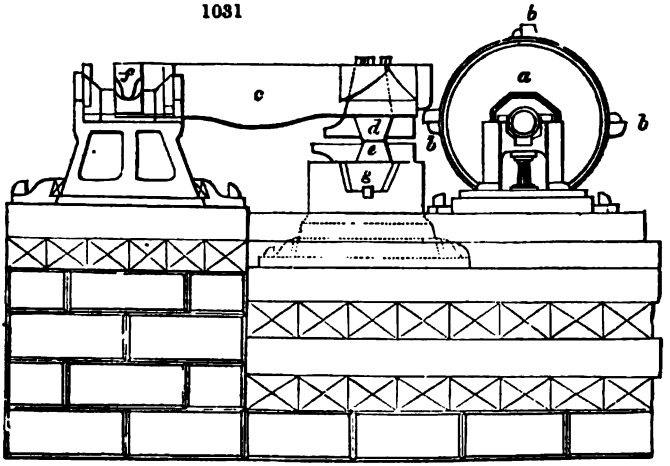
iron retains the last portion of carbon with extraordinary tenacity, and that it can only be made to yield it up by the action of excessive temperature and oxygen; it then passes into a condition of what is called *burnt* iron which Gmelin states, (vol. *v.* p. 205, *English Translation*), is the only variety of bar iron that is free from carbon. This is clearly the condition of the ingots made by Bessemer's process; it is stated, however, that by proper management any desired quantity of carbon may be retained, and it remains to be proved how far this will be practicable on the large scale, and whether those varieties of steel and semi-steel alluded to in the patents can really be produced.

Some interesting experiments on fused wrought iron have recently been made by Mr. Riley of the Dowlais Iron Works. By exposing fragments of block plate from the tin works for two hours to the highest heat of a wind furnace, the fragments being covered with cinder from an old assay, a perfectly fused button weighing 1638 grains was obtained. When cold the mass was crystallised and easily broken, the fracture being in the direction of the planes of cleavage of the crystals; one half of the button being worked out into a $\frac{1}{4}$ inch bar was very soft, with a fine face, and sharp even edges like steel; two peices when welded together worked well at a welding heat, but on cooling to a red heat became cracky and broke. The fracture of the iron before it had been exposed to welding heat was silky and the body was very tough; it could readily be bent back double without cracking. This experiment was repeated several times, with similar results, the fused buttons being very tough and fibrous when cold, but invariably cracking and breaking to pieces after having been subjected to a welding heat. It would appear, therefore, that fused wrought iron is almost a worthless substance. Mr. Riley is engaged in further experiments, which, it is to be hoped, will throw some light on this singular property of fused wrought iron.

Machines for forging and condensing iron. — To prepare the puddle balls for the rolling mills, they have to undergo the process "shingling;" or "blooming;" this is effected either by the hammer or by the squeezer: the latter has almost entirely superseded the former, as it effects the object at less cost, though, perhaps, with hardly such good results as to quality. These mechanisms are moved either by steam engines or by water-wheels. We shall offer some details concerning them.

The main driving shaft usually carries at either end a large toothed wheel, which communicates motion to the different machines through smaller toothed wheels. Of these there are commonly six, four of which drive four different systems of cylinders, and the two others work the hammer and the shears. The different cylinders of an iron work should never be placed on the same arbor, because they are not to move together, and they must have different velocities according to the diameter. In order to economise time and facilitate labour, care is taken to associate on one side of the motive machine the hammer, the shears, and the reducing cylinders, and on the other side, to place the several systems of cylinders for drawing out the iron into bars. For the same reason the puddling furnaces ought to be grouped on the side of the hammer; and the reheating furnaces on the other side of the works.

1031



The hammers, *fig.* 1031, are made entirely of cast iron; they are nearly 10 feet long, and consist usually of two parts, the helve *c*, and the head or pane *d*. The latter

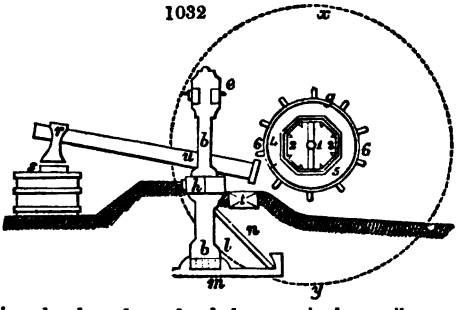
enters with friction into the former, and is retained in its place by wedges of iron or wood. The head consists of several faces or planes receding from each other, for the purpose of giving different forms to the ball lumps. A ring of cast iron *a*, called the *cam-ring bag*, bearing movable cams *b b*, drives the hammer *d*, by lifting it up round its fulcrum *f*, and then letting it fall alternately. In one iron work, this ring was found to be 3 feet in diameter, 18 inches thick, and to weigh 4 tons. The weight of the helve (handle) of the corresponding hammer was 3 tons and a half, and that of the head of the hammer 8 hundred weight.

The anvil *e* consists also of two parts; the one called the pane of the anvil, is the counterpart of the pane of the hammer; it likewise weighs 8 hundred weight. The second *g*, named the stock of the anvil, weighs 4 tons. Its form is a parallelopiped, with the edges rounded. The *bloom* or rough ball, from the puddle furnace, is laid and turned about upon it, by means of a rod of iron welded to each of them, called a *porter*. Since the weight of these pieces is very great, and the shocks very considerable, the utmost precautions should be taken in setting the hammer and its anvil upon a substantial mass of masonry, as shown in the figure, over which is laid a double, or even quadruple flooring of wood, formed of beams placed in transverse layers close to each other. Such beams possess an elastic force, and thereby partially destroy the injurious reaction of the shock. In some works, a six-feet cube of cast iron is placed as a pedestal to the anvil.

Forge hammers are very frequently mounted as levers of the first kind, with the centre of motion about one-third or one-fourth of the length of the helve from the cam wheel. The principle of this construction will be understood by inspection of *fig.* 1032. The short end of the lever which is struck down by the tappet *c*, is driven against the end of an elastic beam *a*, and immediately rebounds, causing the long end to strike a harder blow upon the anvil *s*.

Fig. 1032 is the German forge-hammer; to the left of 1, is the axis of the rotatory

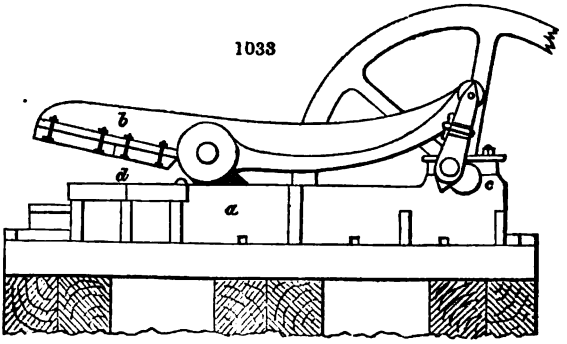
1032



cam, 2, 3, consisting of 8 sides, each formed of a strong broad bar of cast iron, which are joined together to make the octagon wheel. 4, 5, 6, are cast-iron binding rings or hoops made fast by wooden wedges; *b*, *b*, are standards of the frame work *e*, *l*, *m*, in which the helve of the forge hammer has its fulcrum near *u*. *h*, the sole part of the frame. Another cast-iron base or sole is seen at *m*. *n* is a strong stay, to strengthen the frame-work. At *r* two parallel hammers are placed, with cast-iron heads and wooden helves. *s* is the anvil, a very massive piece of cast iron. *t* is the end of a vibrating beam, for throwing back the hammer from it forcibly by recoil. *x y* is the outline of the water-wheel which drives the whole. The cams or tappets are shown mounted upon the wheel 6, *g*, 6.

Squeezers are machines which condense a ball by pressure. They are either single or double, their construction will be readily understood from *fig.* 1033, which represents

1033



a single level squeezer of the simplest construction; the bed plate *a* is cast in one piece; it is 6 feet long, 15 inches wide, and 12 inches high. The whole is screwed down on a solid foundation of stone, brick, or timber: *b* is the movable part, which

makes from 80 to 90 motions per minute. The motion is imparted by the crank *c*, which in turn is driven by means of a strap and pulley by the elementary power. The diameter of the fly wheel is from 3 to 4 feet. The anvil *d* is about two feet in length and from 12 to 14 inches in width; it is a movable plate, at least 3 inches thick, which if injured can be replaced by another; the face of the working part of the lever exactly fits the anvil, and consists of plates attached by means of screws. It is desirable to have all these face plates in small parts of 8 or 10 inches in width, by this means they are secured against breaking by expansion and contraction. The whole machine, including the crank and everything, is made of cast iron, and weighs from 4 to 5 tons. According to Overman this machine is both cheap and durable, and will squeeze 100 tons of iron per week.

Fig. 1034 represents the double squeezer, employed at many English iron works. The drawing is taken from a machine at the Dowlais iron works, figured in Mr. Truran's work. Many other forms are in use.

1034

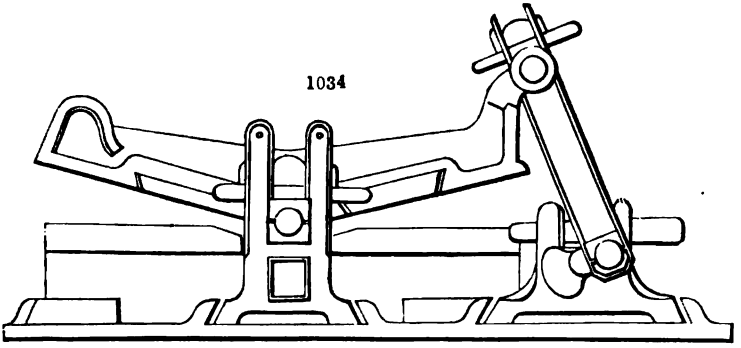
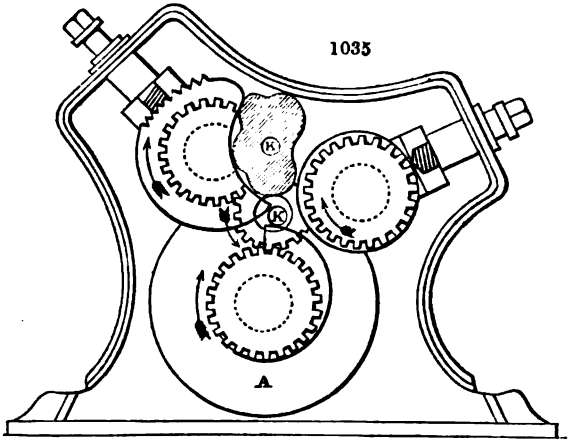


Fig. 1035 represents Brown's patent bloom squeezer. The heated ball of puddled iron K, thrown on the top is gradually pressed between the revolving rollers as it

1035

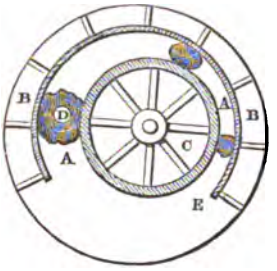


descends, and at last emerges at the bottom, where it is thrown on to a movable "Jacob's ladder," by which it is elevated to the rolls. This machine effects a considerable saving of time, will do the work of 12 or 14 furnaces, and may be constantly going as a feeder to one or two pairs of rolls. There are two distinct forms of this machine; in the one figured the bloom receives only two compressions; in another, which is much more effective it is squeezed four times before it leaves the rolls and falls upon the Jacob's ladder. Another form of squeezer is shown in *fig.* 1036.

A table A A with a ledge rising up from it to a height of about 2 feet, so as to form an open box, is firmly imbedded in masonry; within this is a revolving box, C, of similar character, much smaller than the last, and placed eccentrically in regard to

it. The ball or bloom D is placed between the innermost revolving box C and the outer case A A where the space between them is greatest, and is carried round till it emerges at E, compressed and fit for the rolls.

1036



Cylinders. — The compression between cylinders now effects, in a few seconds, that condensation and distribution of the fibres, which 40 years ago could not be accomplished till after many heats in the furnace, and many blows of the hammer. The cylinders may be distinguished into two kinds: 1, those which serve to draw out the ball, called *puddling rolls*, or roughing rolls, and which are, in fact, reducing cylinders; 2, the cylinders of extension, called *rollers*, for drawing into bars the massive iron after it has received a welding, to make it more malleable. This second kind of cylinders is subdivided into several varieties, according to the patterns of bar iron that are required. These may vary from 2 inches square to less than one-sixth of an inch.

Beneath the cylinders there is usually formed an oblong fosse, into which the scoriæ and the scales fall when the iron is compressed. The sides of this fosse, constructed of stone, are founded on a body of solid masonry, capable of supporting the enormous load of the cylinders. Beams of wood form in some measure the sides of this pit, to which cylinders may be made fast, by securing them with screws and bolts. Massive bars of cast iron are found, however, to answer still better, not only because the uprights and bearers may be more solidly fixed to them, but because the basement of heavy metal is more difficult to shatter or displace, an accident which happens frequently to the wooden beams. A rill of water is supplied by a pipe to each pair of cylinders, to hinder them from getting hot; as also to prevent the hot iron from adhering to the cylinder, by cooling its surface, and perhaps producing on it a slight degree of oxidisement.

The shafts are 1 foot in diameter for the hammer and the roughing rolls; and 6 inches where they communicate motion to the cylinders destined to draw the iron into bars.

The *roughing rolls* are employed either to work out the lump or ball immediately after it leaves the puddling furnace, as in the Welsh forges, or only to draw out the piece, after it has been shaped under the hammer, as is practised in most of the Staffordshire establishments. These roughing cylinders are generally 7 feet long, including the trunnions, or 5 feet between the bearers, and 18 inches diameter; and weigh in the whole from 4 to 4½ tons. They contain from 5 to 7 grooves, commonly of an elliptical form, one smaller than another in regular progression, as is seen in *fig.* 1037. The small axis of each ellipse, as formed by the union of the upper and under grooves, is always placed in the vertical direction, and is equal to the great axis, or horizontal axis of the succeeding groove; so that in transferring the bar from one groove to another, it must receive a quarter of a revolution, whereby the iron gets elongated in every direction. Sometimes the roughing rolls serve as preparatory cylinders, in which case they bear towards one extremity rectangular grooves, as the figure exhibits. Several of these large grooves are bestudded with small asperities analogous to the teeth of files, for biting the lump of iron, and preventing its sliding. On a level with the under side of the grooves of the lower cylinder, there is a plate of cast iron with notches in its edge adapted to the grooves. This piece, called the apron, rests on iron rods, and serves to support the balls and bars exposed to the action of the rollers, and to receive the fragments of ill-welded metal, which fall off during the drawing. The *housing frames* in which the rollers are supported and revolve, are made of great strength. Their height is 5 feet; their thickness is 1 foot in the side perpendicular to the axis of the cylinders, and 10 inches in the other. Each pair of bearers is connected at their upper ends by two iron rods, on which the workmen rest their tongs or pincers for passing the lump or bar from one side of the cylinders to the other.

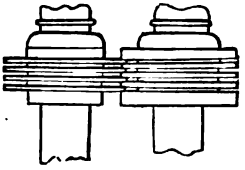
The cods or bushes are each composed of two pieces; the one of hard brass, which presents a cylindrical notch, is framed into the other which is made of cast iron, as is clearly seen in *fig.* 1037.

The iron bar delivered from the square grooves, is cut by the shears into short lengths, which are collected in a bundle in order to be welded together. When this bundle of bars has become hot enough in the furnace, it is conveyed to the rollers, which differ in their arrangement according as they are meant to draw iron from a large or small piece. The first, *fig.* 1037, possess both elliptical and rectangular grooves; are 1 foot in diameter and 3 feet long between the bearers. The bar is not

finished under these cylinders, but is transferred to another pair, whose grooves have the dimensions proper for the bar, with a round, triangular, rectangular, or fillet form. The triangular grooves made use of for square iron, have for their profile an isosceles triangle slightly obtuse, so that the space left by the two grooves together may be a rhombus, differing little from a square, and whose smaller diagonal is vertical. When the bar is to be passed successively through several grooves of this kind, the larger or horizontal diagonal of each following groove is made equal to the smaller or upright of the preceding one, whereby the iron must be turned one fourth round at each successive draught, and thus receive pressure in opposite directions. Indeed the bar is often turned in succession through the triangular and rectangular grooves, that its fibres may be more accurately worked together. The decrement in the capacity of the grooves follows the proportion of 15 to 11.

When it is intended to reduce the iron to a small rod, the cylinders have such a diameter, that three may be set in the same housing frame. The lower and middle cylinders are employed as roughing rollers, while the upper and middle ones are made to draw out the rod. When a rod or bar is to be drawn with a channel or gutter in its face, the grooves of the rollers are suitably formed.

To draw out square rods of a very small size, as nail-rods, a system of small rollers is employed, called *slitters*. Their ridges are sharp-edged, and enter into the opposite grooves 2½ inches deep; so that the flat bar in passing between such rollers is instantaneously divided into several slips. For this purpose the rollers represented in *fig.* 1038, may be put on and removed from the shaft at pleasure.



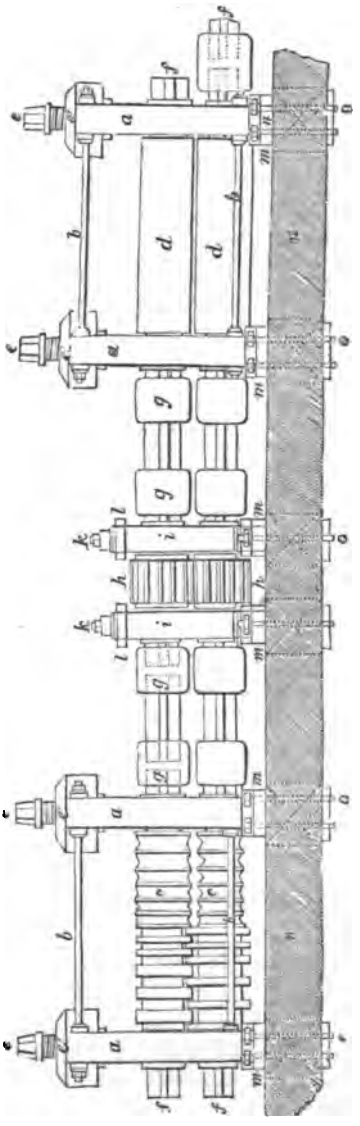
1038

The velocity of the cylinders varies with their dimensions. In one work, cylinders for drawing out iron of from one-third to two-thirds of an inch thick, make 140 revolutions per minute; while those for iron of from two-thirds of an inch to 3 inches, make only 65. In another work, the cylinders for two inch iron, make 95 revolutions per minute; those for iron from two-thirds of an inch to an inch and a third, make 128; and those for bars from one-third to two-thirds of an inch, 150. The *roughing rollers* move with only one-third the velocity of the drawing cylinders.

The shingling and plate-rolling mill is represented in *fig.* 1037. The shingling mill, for converting the blooms from the balling furnace into bars, consists of two sets of grooved cylinders, the first being called *puddling rolls* or *roughing rolls*; the second are for reducing or drawing the iron into mill-bars, and are called simply *rolls*.

a, *a*, *a*, *a*, are the powerful uprights or standards called *housing frames*, of cast iron, in which the gudgeons of the rolls are set to revolve; *b*, *b*, *b*, *b*, are bolt rods for bind-

1037



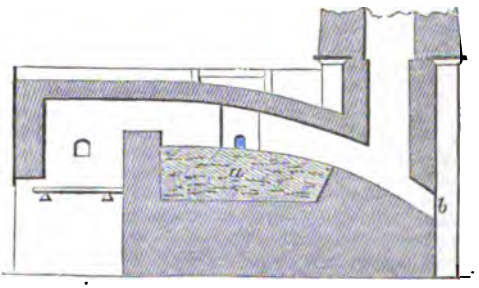
ing these frames together at top and bottom; *c*, are the roughing rolls, having each a series of triangular grooves, such that between those of the upper and under cylinder, rectangular concavities are formed in the circumference with slightly sloping sides. The end groove to the right of *c*, should be channelled like a rough file, in order to take the better hold of the blooms, or to bite the metal as the workmen say; and give it the preparatory elongation for entering into and passing through the remaining grooves till it comes to the square ones, where it becomes a mill-bar. *d*, *d*, are the smooth cylinders, hardened upon the surface, or *chilled*, as it is called, by being cast in iron moulds for rolling iron into plates or hoops. *e*, *e*, *e*, *e*, are strong screws with rectangular threads, which work by means of a wrench or key, into the nuts *e'* *e'* *e'* *e'*, fixed in the standards; they serve to regulate the height of the plummer blocks or bearers of the gudgeons, and thereby the distance between the upper and under cylinders. *f* is a junction shaft; *g*, *g*, *g*, are solid coupling boxes, which embrace the two separate ends of the shafts, and make them turn together. *h*, *h*, are junction pinions, whereby motion is communicated from the driving shaft *f*, through the under pinion to the upper one, and thus to both upper and under rolls at once. *i*, *i*, are the pinion standards in which their shafts run; they are smaller than the uprights of the rolls. *k*, *k*, are screws for fastening the head pieces *l* to the top of the pinion standards. All the standards are provided with sole plates *m*, whereby they are screwed to the foundation beams *n* of wood, or preferably iron, as shown by the dotted lines; *o*, *o*, are the binding screw bolts. Each pair of rolls at work is kept cool by a small stream of water let down upon it from a pipe and stop-cock.

In the cylinder drawing, the workman who holds the ball in tongs passes it into the first of the elliptical grooves, and a second workman, on the other side of the cylinders, receives this lump and hands it over to the first, who repasses it between the rollers after bringing them somewhat closer to each other by giving a turn to the adjusting pressure screws. After the lump has passed five or six times through the same groove it has got an elliptical form, and is called in England a *bloom*. It is next passed through a second groove of less size, which stretches the iron bar. In this state it is subjected to a second pair of cylinders, by which the iron is drawn into flat bars four inches broad and half an inch thick. Fragments of the ball or bloom fall round about the cylinders, which are afterwards added to the puddling charge. In a minute and a half the rude lump is transformed into bars with a neatness and rapidity which the inexperienced eye can hardly follow. A steam engine of thirty horse power can rough down in a week 200 tons of coarse iron.

This iron, called mill-bar iron, is however of too inferior a quality to be employed in any machinery, and it is subjected to another operation, which consists in welding several pieces together, and working them into a mass of the desired quality. The iron bars, while still hot, are cut by the shears into a length proportional to the size of the iron bar that is wanted, and four rows of these are usually laid over each other into a heap or pile which is placed in the *re-heating* furnace, and exposed to a free circulation of heat, one pile being set crosswise over another. In a half or three quarters of an hour the iron is hot enough, and the pieces now sticking together are carried in successive piles to the bar drawing cylinders to be converted into strong bars, which are reckoned of middle quality. When a very tough iron is wanted, as for anchors, another welding and rolling must be given. In the re-heating ovens the loss is from 8 to 10 per cent. on the large bar, and from 10 to 12 in smaller work. The consumption of coals in heating the large piles averages 7 cwts. to the ton of iron charged; in the smaller sizes 10 cwts.; and in heating the guide rolled iron 13 cwts.

The re-heating furnace is shown in section in *fig.* 1039: it differs but little from a puddling furnace. The whole interior, with the exception of the hearth *a*, is made of fire-brick; the hearth is made of sand. For this purpose a pure siliceous sand is required; the coarser the better. The hearth slopes considerably towards the flue, the object of which is to keep the hearth dry and hard. The iron wasted in re-heating combines with the silica of the sand, forming a very fusible cinder, which flows off through the opening at *b*, at which there is a small fire to keep the cinder liquid. The thickness of the sand bottom is from 6 to 12 inches, resting on fire-brick: it generally requires re-making after two or three heats. The height of the fire-brick arch, or its distance from the sand

1039



bottom, is from 8 to 12 inches. The area of the fire-place averages 12 feet, and the width of the furnace varies from 5 to 8 feet. When the piles are charged into the furnace the door is shut, and fine coal is dusted around its edges to exclude the cold air; the temperature is raised to the highest intensity as quickly as possible, and the workman turns the piles over from time to time that they may be brought to an uniform welding heat in the shortest possible time.

It is thought by many that a purer iron is obtained by subjecting the balls as they come out of the puddling furnace to the action of the hammer at first rather than to the roughing rollers, as by the latter process vitrified specks remain in the metal, which the hammer expels. Hence in some works the balls are first worked under the forge hammer, and these *stampings* being afterwards heated in the form of pies or cakes, piled over each other, are passed through the roughing mills.

Bars intended for boiler or tin plates are made from the best cold blast mine iron. The raw pig is refined in the usual manner with coke, the loss amounting to from 2½ to 3 cwts. per ton. It is then refined a second time with charcoal, the loss amounting again to from 2½ to 3 cwts. per ton. After this second refining it is beaten into flat plates white hot by the tilt hammer and thrown into cold water; the sudden chilling makes it more easily broken into small slabs. The slabs are piled in heaps and welded in the *hollow* fire, coke being the fuel; the slabs are laid across the fire, and do not come into contact with the fuel; the blast is thrown under the fuel, and the heat is immense; when the piles are nearly at the fusing point, they are withdrawn and passed under the rollers; they are again heated in the hollow fire, then again rolled and heated a third time in the ordinary reverberatory furnace, after which they are drawn out into flat bars for boiler plates, or for tin plate: the loss in these operations amounts to from 3½ to 4 cwt. per ton. About 9 heats are accomplished in 12 hours, each heat consisting of 2¼ cwts. of refined metal, and consuming 5 baskets of charcoal.

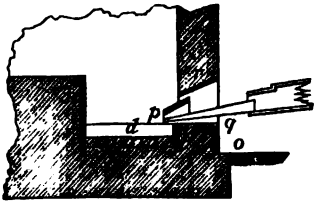
The bars intended for tin plates are repeatedly heated and rolled until of the requisite thinness, the plates are then cut into squares, and annealed by exposing them for several hours to heat in covered iron boxes, being allowed to cool very slowly; this gives the plates the proper degree of pliancy. The next operation is that of *pickling*; the plates are immersed in dilute sulphuric acid for the purpose of removing from their surfaces all oxide and dirt; after remaining in the acid for the requisite time, they are thoroughly washed in successive troughs of water, and then dried in sawdust; finally the surfaces of the metal are prepared for the reception of the tin, by rubbing them with leather upon cushions of sheepskin. The spent sulphuric acid is run out into evaporating pans, and the sulphate of iron crystallised out. In order to tin the plates, they are immersed in a bath of melted tin, the surface of which is covered with tallow or palm oil; when sufficiently covered, they are transferred to the *brusher* on the left hand side of the tinner; he passes a rough brush rapidly over each side of the plate, whereby the superfluous tin is removed; he then plunges the plate again into the tin bath, and passes it on to his left hand neighbour, who gives it a washing. The plate passes through several hands before it is dried. Great skill is required in the tinning process; nevertheless in a well-conducted work the *wasters* do not amount to more than 10 per cent.; a small percentage of which are so bad as to require to be reworked. Great care is taken to avoid waste, tin being worth 150*l.* per ton. A box of 225 sheets of tin plates 10 inches by 14 consumes about 8½ lbs. of tin. See TIN PLATE.

The processes pursued in the smelting works of the Continent have frequently in view to obtain from the ore malleable iron directly, in a pure or nearly pure state. The furnaces used for this purpose are of two kinds, called in French, 1. *Feux de Loupes*, or *Forges Catalanes*; and 2. *Fourneaux à pièce*, or *Forges Allemandes*.

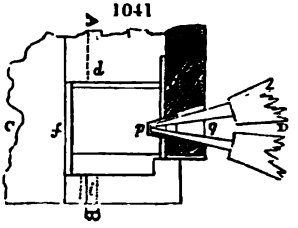
In the Catalan, or French method, the ore previously roasted in a kiln is afterwards strongly torrefied in the forge before the smelting begins; operations which follow in immediate succession. Ores treated in this way should be very fusible and very rich; such as black oxide of iron, hæmatites, and certain spathose iron ores. From 100 parts of ore, 50 of metallic iron have been procured, but the average product is 35. The furnaces employed are rectangular hearths, *figs.* 1040 and 1041, the water-blowing machine being employed to give the blast. See METALLURGY. There are three varieties of this forge; the Catalan, the Navarrese, and the Biscayan. The dimensions of the first, the one most generally employed, are as follows: 21 inches long, in the direction *p f*, *fig.* 1041; 18½ broad, at the bottom of the hearth or *creuset*, in the line A B; and 17 inches deep, *fig.* 1040. The tuyère, *q p*, is placed 9½ inches above the bottom, so that its axis is directed towards the opposite side, about 2 inches above the bottom. But it must be movable, as its inclination needs to be changed, according to the stage of the operation, or the quantity of the ores. It is often raised or lowered with pellets of clay; and even with a graduated circle, for the workmen make a great mystery of

this matter. The hearth is lined with a layer of *brasque* (loam and charcoal dust worked together), and the ore after being roasted is sifted; the small powder being set aside to be used in the course of the operation. The ore is piled up on the side opposite to the blast in a sharp saddle ridge, and it occupies one-third of the furnace. In the remaining space of two-thirds, the charcoal is put. To solidify the small ore on the hearth, it is covered with moist cinders mixed with clay.

1040



1041



The fire is urged with moderation during the first two hours, the workman being continually employed in pressing down more charcoal as the former supply burns away, so as to keep the space full, and prevent the ore from crumbling down. By a blast so tempered at the beginning, the ore gets well calcined, and partially reduced in the way of cementation. But after two hours, the full force of the air is given; at which period the fusion ought to commence. It is easy to see whether the torrefaction be sufficiently advanced, by the aspect of the flame, as well as of the ore, which becomes spongy or cavernous; and the workman now completes the fusion, by detaching the pieces of ore from the bottom, and placing them in front of the tuyère. When the fine siftings are afterwards thrown upon the top, they must be watered, to prevent their being blown away, and to keep them evenly spread over the whole surface of the light fuel. They increase the quantity of the products, and give a proper fusibility to the scoriæ. When the scoriæ are viscid, the quantity of siftings must be diminished; but if thin, they must be increased, The excess of slag is allowed to run off by the *chio* or floss hole. The process lasts from five to six hours, after which the pasty mass is taken out, and placed under a hammer to be cut into lumps, which are afterwards forged into bars.

Each mass presents a mixed variety of iron and steel; in proportions which may be modified at pleasure; for by using much of the siftings, and making the tuyère dip towards the sole of the hearth, iron is the chief product; but if the operation be conducted slowly, with a small quantity of siftings, and an upraised tuyère, the quantity of steel is more considerable. This primitive process is favourably spoken of by M. Brongniart. The weight of the lump of metal varies from 200 to 400 pounds. As the consumption of charcoal is very great, amounting in the Palatinate or Rheinkreis to seven times the weight of iron obtained, though in the Pyrenees it is only thrice, the Catalan forge can be profitably employed only where wood is exceedingly cheap and abundant.

The *Fourneaux à pièce* of the French, or *Stuck-ofen* of the Germans, resembles *fig.* 575 (Copper); the tuyère (not shown there) having a dip towards the bottom of the hearth, where the smelted matter collects. When the operation is finished, that is at least once in every 24 hours, one of the sides of the hearth must be demolished, to take out the pasty mass of iron, more or less pure. This furnace holds a middle place in the treatment of iron, between the Catalan forge and the cast-iron *floss-ofen*, or high-blast furnaces. The *stuck-ofen* are from 10 to 15 feet high, and about 3 feet in diameter at the hearth. Most usually there is only one aperture for the tuyère and for working; with a small one for the escape of the slag; on which account, the bellows are removed to make way for the lifting out of the lump of metal, which is done through an opening left on a level with the sole, temporarily closed with bricks and potter's clay, while the furnace is in action.

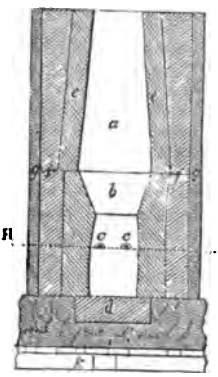
This outlet being closed, and the furnace filled with charcoal, fire is kindled at the bottom. Whenever the whole is in combustion, the roasted ore is introduced at the top in alternate charges with charcoal, till the proper quantity has been introduced. The ore falls down; and whenever it comes opposite to the tuyère the slag begins to flow, and the iron drops down and collects at the bottom of the hearth into the mass or *stuck*; and in proportion as this mass increases, the *floss-hole* for the slag and the tuyère is raised higher. When the quantity of iron accumulated in the hearth is judged to be sufficient, the bellows are stopped, the scoriæ are raked off, the little brick wall is taken down, and the mass of iron is removed by rakes and tongs. This mass is then flattened under the hammer into a cake from 3 to 4 inches thick, and is cut into two

lumps, which are submitted to a new operation; where it is treated in a peculiar refinery, lined with charcoal *brasque*, and exposed to a nearly horizontal blast. The above mass seized in the jaws of powerful tongs, is heated before the tuyère; a portion of the metal flows down to the bottom of the hearth, loses its carbon in a bath of rich slags or fused oxides, and forms thereby a mass of iron thoroughly refined. The portion that remains in the tongs furnishes steel, which is drawn out into bars.

This process is employed in Carniola for smelting a granular oxide of iron. The mass or *stuck* amounts to from 15 to 20 hundred-weight after each operation of 24 hours. Eight strong men are required to lift it out, and to carry it under a large hammer, where it is cut into pieces of about 1 cwt. each. These are afterwards refined, and drawn into bars as above described. These furnaces are now almost generally abandoned on the Continent, in favour of *charcoal high or blast furnaces.*

Fig. 1042 represents a *schachtofen* (but without the tuyère, which may be supposed to be in the usual place), and is, like all the continental *Hauts Fourneaux*, remarkable for the excessive thickness of its masonry. The charge is put in at the throat, near the summit of the octagonal or square concavity, for they are made of both forms. At the bottom of the hearth there is a dam-stone with its plate, for permitting the overflow of the slag, while it confines the subjacent fluid metal: as well as a tymp stone with its plate, which forms the key to the front of the hearth; the boshes are a wide funnel, almost flat, to obstruct the easy descent of the charges, whereby the smelting with charcoal would proceed too rapidly. The bottom of the hearth is constructed of two large stones, and the hinder part of one great stone, called in German *rückstein* (back stone), which the French have corrupted into *rustine*. In other countries of the Continent, the boshes are frequently a good deal more tapered downwards, and the hearth is larger than here represented. The refractory nature of the Hartz iron ores is the reason assigned for this peculiarity.

1042



In Sweden there are blast-furnaces, *schachtofen*, 35 feet in height, measured from the boshes above the line of the hearth, or *creuset*. Their cavity has the form of an elongated ellipse, whose small diameter is 8 feet across, at a height of 14 feet above the bottom of the hearth; hence, at this part, the interior space constitutes a belly corresponding with the upper part of the boshes. In other respects the details of the construction of the Swedish furnaces resemble the one figured above. Marcher relates that a furnace of that kind whose height was only 30 feet, in which brown hydrate of iron (*hæmatite*) was smelted, yielded 47 per cent. in cast iron, at the rate of 5 hundred weight a day, or 36 hundred-weight one week after another; and that in the production of 100 pounds of cast iron, 130 pounds of charcoal were consumed. That furnace was worked with forge bellows, mounted with leather.

The decarburation of cast iron is merely a restoration of the carbon to the surface in tracing inversely the same progressive steps as had carried it into the interior during the smelting of the ore. The oxygen of the air, acting first at the surface of the cast metal upon the carbon which it finds there, burns it: fresh charcoal, oozing from the interior, comes then to occupy the place of what had been dissipated; till, finally, the whole carbon is transferred from the centre to the surface, and is there converted into either carbonic acid gas or oxide of carbon; for no direct experiment has hitherto proved which of these is the precise product of this combustion.

This diffusibility of carbon through the whole mass of iron constitutes a movement by means of which cast iron may be refined even without undergoing fusion, as is proved by a multitude of phenomena. Every workman has observed that steel loses a portion of its steely properties every time it is heated in contact with air.

On the above principle, cast iron may be refined at one operation. Three kinds of iron are susceptible of this continuous process:—1. The speckled cast-iron, which contains such a proportion of oxygen and carbon as with the oxygen of the air and the carbon of the fuel may produce sufficient and complete saturation, but nothing in excess. 2. The dark grey cast-iron. 3. The white cast-iron. The nature of the crude metal requires variations both in the form of the furnaces, and in the manipulations.

Indeed malleable iron may be obtained directly from the ores by one fusion. This mode of working is practised in the Pyrenees to a considerable extent. All the ores of iron are not adapted for this operation. Those in which the metallic oxide is mixed with much earthy matter, do not answer well; but those composed of the pure

black oxide, red oxide, and carbonate, succeed much better. To extract the metal from such ores, it is sufficient to expose them to a high temperature, in contact either with charcoal, or with carbonaceous gases; the metallic oxide is speedily reduced. But when several earths are present, these tend continually, during the vitrification which they suffer, to retain in their vitreous mass the unreduced oxide of iron. Were such earthy ores, as our ironstones, to be put into the low furnaces called *Catalan*, through which the charges pass with great rapidity, and in which the contact with the fuel is merely momentary, there would be found in the crucible or hearth merely a rich metallic glass, instead of a lump of metal.

In smelting and refining by a continuous operation, three different stages may be distinguished: — 1. The roasting of the ore to expel the sulphur, which would be less easily separated afterwards. The roasting dissipates likewise the water, the carbonic acid, and any other volatile substances which the minerals may contain. 2. The deoxidisement and reduction to metal by exposure to charcoal or carburetted vapours. 3. The melting, agglutination, and refining of the metal to fit it for the heavy hammers where it gets nerve. There are several forges in which these three operations seem to be confounded into a single one, because, although still successive, they are practised at one single heating without interruption. In other forges, the processes are performed separately, or an interval elapses between each stage of the work. Three systems of this kind are known to exist: — 1. The Corsican method; 2. The Catalan with wood charcoal; and, 3. The Catalan with coke.

The furnaces of Corsica are a kind of semicircular basins, 18 inches in diameter, and 6 inches deep. These are excavated in an area, or a small elevation of masonry, 8 or 10 feet long by 5 or 6 broad, and covered in with a chimney. This area is quite similar to that of the ordinary hearths of our blast-furnaces.

The tuyère stands 5 or 6 inches above the basin, and has a slight inclination downwards. In Corsica, and the whole portion of Italy adjoining the Mediterranean shores, the iron ore is an oxide similar to the specular ore of the Isle of Elba. This ore contains a little water, some carbonic acid, occasionally pyrites, but in small quantity. Before deoxidising the ore, it is requisite to expel the water and carbonic acid combined with the oxide, as well as the sulphur of the pyrites.

The operations of roasting, reduction, fusion, and agglutination are executed in the same furnace. These are indeed divided into two stages, but the one is a continuation of the other. In the first, the two primary operations are performed at once;—the reduction of a portion of the roasted ore is begun at the same time that a portion of the raw ore is roasted: these two substances are afterwards separated. In the second stage, the deoxidisement of the metal is continued, which had begun in the preceding stage; it is then melted and agglutinated, so as to form a ball to be submitted to the forge-hammer.

The roasted pieces are broken down to the size of nuts, to make the reduction of the metal easier. In executing the first step, the basin and area of the furnace must be lined with a *brasque* of charcoal dust, 3, 4, or even 5 inches thick: over this *brasque* a mound is raised with lumps of charcoal, very hard, and 4 or 5 inches high. A semicircle is framed round the tuyère, the inner radius of which is 5 or 6 inches. This mass of charcoal is next surrounded with another pile of the roasted and broken ores, which must be covered with charcoal dust. The whole is sustained with large blocks of the raw ore, which form externally a third wall.

These three piles of charcoal, with roasted and unroasted ore, are raised in three successive beds, each 7 inches thick: they are separated from each other by a layer of charcoal dust of about an inch, which makes the whole 24 inches high. This is afterwards covered over with a thick coat of pounded charcoal.

The blocks of raw ore which compose the outward wall form a slope; the larger and stronger pieces are at the bottom, and the smaller in the upper part. The large blocks are sunk very firmly into the charcoal dust, to enable them better to resist the pressure from within.

On the bottom of the semicircular well formed within the charcoal lumps, kindled pieces are thrown, and over these, pieces of black charcoal; after which the blast of a water-blowing machine (*trompe*) is given. The fire is kept up by constantly throwing charcoal into the central well. At the beginning of the operation it is thrust down with wooden rods, lest it should affect the building; but when the heat becomes too intense for the workmen to come so near the hearth, a long iron rake is employed for the purpose. At the end of about 3 hours, the two processes of roasting and reduction are commonly finished: then the raw ore no longer exhales any fumes, and the roasted ore, being softened, unites into lumps more or less coherent.

The workman now removes the blocks of roasted ore which form the outer casing, rolls them to the spot where they are to be broken into small pieces, and pulls down the *brasque* (small charcoal) which surrounds the mass of reduced ore.

The second operation is executed by cleaning the basin, removing the slags, covering the basin anew with 2 or 3 brasques (coats of pounded charcoal), and piling up to

the right and the left two heaps of charcoal dust. Into the interval between these conical piles two or three baskets of charcoal are cast, and on its top some cakes of the reduced crude metal being laid, the blast is resumed. The cakes, as they heat, undergo a sort of liquation, or sweating, by the action of the earthy glasses on the unreduced black oxide present. Very fusible slags flow down through the mass; and the iron, reduced and melted, passes finally through the coals, and falls into the slag basin below. To the first parcel of cakes others are added in succession. In proportion as the slags proceeding from these run down, and the melted iron falls to the bottom, the thin slag is run off by an upper overflow or *chio* hole, and the reduced iron kept by the heat in the pasty condition, remains in the basin: all its parts get agglutinated, forming a soft mass, which is removed by means of a hooked pole in order to be forged. Each lump or *bloom* of malleable iron requires 3 hours and a half for its production.

The iron obtained by this process is in general soft, very malleable, and but little steely. In Corsica four workmen are employed at one forge. The produce of their labour is only about 4 cwt. of iron from 10 cwt. of ore and 20 of charcoal, mingled with wood of beech and chestnut. Though their ore contains on an average 65 per cent. of iron, only about 40 parts are extracted; evincing a prodigious waste, which remains in the slags.

The difference between the Corsican and the Catalonian methods consists in the latter roasting the ore at a distinct operation, and employing a second one in the reduction, agglutination, and refining of the metal. In the Catalonian forges, 100 pounds of iron are obtained from 300 pounds of ore and 310 pounds of charcoal; being a produce of only 33 per cent. It may be concluded that there is a notable loss, since the sparry iron ores, which are those principally smelted, contain on an average from 54 to 56 per cent. of iron. The same ores smelted in the ordinary blast furnace produce about 45 per cent. of cast iron.

On the Continent, iron is frequently refined from the cast metal of the blast furnaces by three operations, in three different ways. In one, the pig being melted, with aspersion of water, a cake is obtained, which is again melted in order to form a second cake. This being treated in the refinery fire, is then worked into a *bloom*. In another system, the pig iron is melted and cast into plates: these are melted anew in order to obtain crude balls, which are finally worked into blooms. In a third mode of manufacture, the pig-iron is melted and cast into plates, which are roasted, and then strongly heated, to form a bloom.

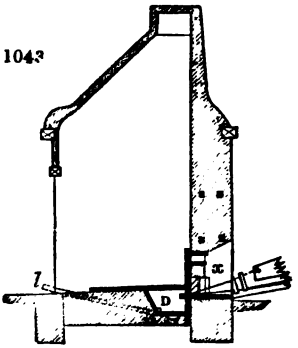
The French fusible ores, such as the silicates of iron, are very apt to smelt into white cast iron. An excess of fluxes, light charcoals, too strong a blast, produce the same results. A surcharge of ores which deranges the furnace and affords impure slags mixed with much iron, too rapid a slope in the boshes, too low a degree of heat, and too great condensation of the materials in the upper part of the furnace; all tend also to produce a white cast iron. In its state of perfection, white cast iron has a silver colour, and a bright metallic lustre. It is employed frequently in Germany for the manufacture of steel, and is then called *steel floss*, or *lamellar floss*, a title which it still retains, though it be hardly silver white, and has ceased to be foliated. When its colour takes a bluish grey tinge, and its fracture appears striated or splintery, or when it exhibits grey spots, it is then styled *flower floss*. In a third species of white cast iron we observe still much lustre, but its colour verges upon grey, and its texture is variable. Its fracture has been sometimes compared to that of a broken cheese. This variety occurs very frequently. It is a white cast iron, made by a surcharge of ore in the furnace. If the white colour becomes less clear and turns bluish, if its fracture be contorted, and contains a great many empty spaces or air-cells, the metal takes the name of *cavernous-floss*, or *tender floss*. The whitest metal cannot be employed for casting. When the white is mixed with the grey cast iron, it becomes *riband* or *trout* cast iron.

The German refining forge.—*Figs.* 1043, 1044, represent one of the numerous refinery furnaces so common in the Hartz. The example is taken from the *Mandelholz* works, in the neighbourhood of Elbingerode. *Fig.* 1044 is an elevation of this forge. D is the refinery hearth, provided with two pairs of bellows. *Fig.* 1043 is a vertical section, showing particularly the construction of the crucible or hearth in the refinery forge D. C is an overshot water wheel, which gives an alternate impulsion to the two bellows *a b* by means of the revolving shaft *c*, and the cams or tappets *d f e g*.

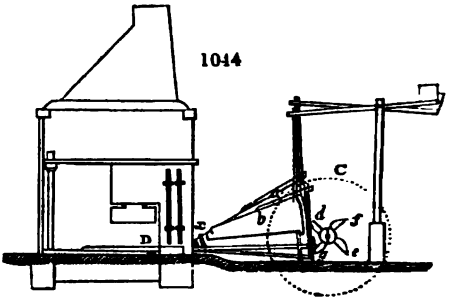
D, the hearth, is lined with cast-iron plates. Through the pipe *l*, cold water may be introduced, under the bottom plate *m*, in order to keep down, when necessary, the temperature of the crucible, and facilitate the solidification of the *loupe* or bloom. An orifice *n*, *figs.* 1043, 1044, called the *chio* (floss hole), allows the melted slag or cinder to flow off from the surface of the melted metal. A copper pipe or nose piece conducts the blast of both bellows into the hearth, as shown at *b x*, *fig.* 1044.

The substance subjected to this mode of refinery is a grey carbonaceous cast iron, from the works of Rothehütte. The hearth D, being filled and heaped over with live

1043



1044



charcoal, upon the side opposite to the tuyère *x*, *figs.* 1043, 1044, long pigs of cast iron are laid with their ends sloping downwards, and are drawn forwards successively into the hearth by a hooked poker, so that the extremity of each may be plunged into the middle of the fire, at a distance of 6 or 8 inches from the mouth of the tuyère. The workman proceeds in this way till he has melted enough of metal to form a *loupe*. The cast iron, on melting, falls down in drops to the bottom of the hearth; being covered by the fused slags, or vitreous matters more or less loaded with oxide of iron. After running them off by the orifice *n*, he then works the cast iron by powerful stirring with an iron rake (*ringard*), till it is converted into a mass of a pasty consistence.

During this operation, a portion of the carbon contained in the cast iron combines with the atmospherical oxygen supplied by the bellows, and passes off in the form of carbonic oxide and carbonic acid. When the lump is coagulated sufficiently, the workman turns it over in the hearth, then increases the heat so as to melt it afresh, meanwhile exposing it all round to the blast, in order to consume the remainder of the carbon, that is, till the iron has become ductile, or refined. If one fusion should prove inadequate to this effect, two are given. Before the conclusion, the workman runs off a second stratum of vitreous slag, but at a higher level, so that some of it may remain upon the metal.

The weight of such a *loupe* or *bloom* is about 2 cwts., being the product of 2 cwts. and $\frac{7}{10}$ of pig iron; the loss of weight is therefore about 26 per cent. 149 pounds of charcoal are consumed for every 100 pounds of bar iron obtained. The whole operation lasts about 5 hours. The bellows are stopped as soon as the bloom is ready; this is immediately transferred to a forge hammer, the cast-iron head of which weighs 8 or 9 cwts. The bloom is greatly condensed thereby, and discharges a considerable quantity of semi-fluid cinder. The lump is then divided by the hammer and a chisel into 4 or 6 pieces, which are re-heated, one after another, in the same refinery fire, in order to be forged into bars, whilst another pig of cast iron is laid in its place, to prepare for the formation of a new bloom. The above process is called by the Germans *klump-frischen*, or lump refining. It differs from the *durch-brech-frischen*, because in the latter the lump is not turned over in mass, but is broken, and exposed in separate pieces successively to the refining power of the blast near the tuyère. The French call this *affinage par portions*; it is much lighter work than the other.

The quality of the iron is tried in various ways; as, first, by raising a bar by one end, with the two hands over one's head, and bringing it forcibly down to strike across a narrow anvil at its centre of percussion, or one-third from the other extremity of the bar; after which it may be bent backwards and forwards at the place of percussion several times; 2, a heavy bar may be laid obliquely over props near its end, and struck strongly with a hammer with a narrow pane, so as to curve it in opposite directions; or while heated to redness, they may be kneaded backwards and forwards at the same spot, on the edge of the anvil. This is a severe trial, which the hoop L, Swedish iron, bears surprisingly, emitting as it is hammered a phosphoric odour, peculiar to it and to the bar iron of Ulverstone, which also resembles it in furnishing a good steel. The forging of a horse-shoe is reckoned a good criterion of the quality of iron. Its freedom from flaws is detected by the above modes; and its linear strength may be determined by suspending a scale to the lower end of a hard-drawn wire, of a given size, and adding weights till the wire breaks. The treatises of Barlow, Tredgold, Hodgkinson, and Fairbairn may be consulted with advantage

on the methods of proving the strength of different kinds of iron, in a great variety of circumstances.

Dry assay of iron ores.—The object of a *dry assay* of an iron ore is to ascertain by an experiment on a small scale the amount of iron which the ore should yield when smelted on the large scale in the blast furnace. For this purpose the metal must be deoxidised, and such a temperature produced as to melt the metal and the earths associated with it in the ore, so that the former may be obtained in a dense button at the bottom of the crucible, and the latter in a lighter glass or slag above it. Such a temperature can only be obtained in a wind furnace connected with a chimney at least 30 feet in height, and when made expressly for assaying the furnace, is generally built of such a size that four assays may be made at the same time, viz. about 14 inches square, and 2 feet in depth from the under side of the cover to the moveable bars of iron which form the grate. In order that the substances associated with the iron in the ore should form a fusible compound, it is usually requisite to add a flux, the nature of which will depend upon the character of the ore under examination. Berthier divides iron ores into five classes: 1. The almost pure oxides, such as the *magnetic oxide, oligistic iron*, and the *hæmatites*; 2. Ores containing silica, but free or nearly so from any other admixture; 3. Ores containing silica and various bases, but little or no lime; 4. Ores containing one or more bases, such as *lime, magnesia, alumina, oxide of manganese, oxide of titanium, oxide of tantalum, oxide of chromium*, or *oxide of tungsten*, but *little* or no *silica*; 5. Ores containing *silica, lime*, and *another base*, and which are fusible alone. Ores of the first class may be reduced without any flux, but it is always better to employ one, as it greatly facilitates the formation of the button; borax may be used, or, better, a fusible earthy silicate, such as ordinary flint glass. Ores of the second class require some base to serve as a flux, such as carbonate of soda, a mixture of carbonate of lime and clay, or of carbonate of lime and dolomite: ores of the third class are mixed with carbonate of lime in the proportion of from one-half to three-fourths of the weight of the foreign matter present in the ore. Ores of the fourth class require as a flux silica in the form of pounded quartz, and generally also some lime; the manganesian spathic ores which belong to this class may be assayed with the addition of silica alone, but the magnesian spathic ores require lime. Ores of the fifth class require no flux.

Method of conducting the assay.—One hundred grains of the ore finely pulverised and passed through a silk sieve are well mixed with the flux, and the mixture introduced into the smooth concavity made in the centre of a crucible that has been lined with charcoal; the lining of the crucible is effected by partially filling it with coarsely powdered and slightly damped charcoal or *brasque*, which is then rammed into a solid form by the use of a light wooden pestle. The mingled ore and flux must be covered with charcoal. The crucible thus filled is closed with an earthen lid luted on with fire clay; and it is then set on its base in the air furnace. The heat should be very slowly raised, the damper remaining closed during the first half-hour. In this way the water of the damp charcoal exhales slowly, and the deoxidation of the ore is completed before the fusion begins: if the heat were too high at first the luting would probably split, and moreover, the slag formed would dissolve some oxide of iron, which would be lost to the button, and thus give an erroneous result. After half an hour the damper is gradually opened, and the furnace being filled with fresh coke, the temperature is raised progressively to a white heat, at which pitch it must be maintained for a quarter of an hour; the damper is then closed and the furnace is allowed to cool. As soon as the temperature is sufficiently reduced, the crucible is removed and opened over a sheet of brown paper; the *brasque* is carefully removed, and the button of cast iron taken out and weighed. If the experiment has been entirely successful the iron will be found at the bottom of the crucible in a small rounded button, and the slag will be entirely free from any adhering metallic globules, and will resemble in appearance green bottle glass; should, however, the slag contain small metallic particles, the experiment is not necessarily a failure, as they may generally be recovered by washing and the magnet. But if on breaking the crucible, the reduced metal should be found in a partially melted state and not collected into a distinct mass, it indicates either too low a temperature or an improper selection of fluxes, and the experiment must be repeated. The iron obtained is not chemically pure, but contains carbon, and if the ore is manganiferous, manganese; the result is therefore somewhat too high, though indicating with sufficient exactness for all manufacturing purposes the richness of the ore assayed.

Humid assay of iron ores.—The quantitative determination of the various substances that occur in iron ores, demands on the part of the operator a considerable amount of skill and patience, and can only be profitably undertaken by those who have acquired in the laboratory a thorough acquaintance with analytical operations. As, however, much attention has of late years been bestowed on the composition of

iron ores, and as certain elements, viz. *manganese*, *sulphur*, and *phosphorus*, are frequently present, which very considerably affect their commercial value, we deem it right to give a detailed account of the operations to be performed in order to arrive at an accurate knowledge of the composition of an ore.

Taking for illustration a specimen of the most complicated composition, the substances besides iron to be looked for, and estimated, are *water* (*hygroscopic* and *combined*), organic *matter*, *sulphur* (as *sulphuric acid*, and as *bisulphide of iron*), *phosphoric acid*, *carbonic acid*, *silicic acid*, *oxide of manganese*, *alumina*, *lime*, and *alkalies*; *lead*, *tin*, *copper*, and *arsenic*, are also occasionally met with; these metals are sought for when a suspicion of their presence is entertained by a special operation on a large quantity of ore.

Too great care cannot be bestowed on the *sampling* of ores intended for analysis; to expend so much time and labour on an isolated specimen (unless for a special object) is worse than useless; the sample operated upon should be selected from a large heap, which should be thoroughly gone over, and several dozen pieces taken from different parts; these should be coarsely powdered and mixed, and about half a pound taken from the mass should be preserved in a well corked bottle for examination.

1. *Determination of water* (*hygroscopic and combined*). — About 50 grains of the ore are dried in the water oven till no further loss of weight is experienced; the loss indicates the hygroscopic water; the residue is introduced into a tube of hard glass, to which is adapted a weighed tube containing chloride of calcium; the powder is then gradually raised to a low red heat, the combined water is thereby expelled, and its amount determined by the increase in weight of the chloride of calcium tube. Some ores (the hydrated hæmatites) contain as much as 12 per cent. of combined water.

2. *Sulphuric acid and sulphur.* — From 30 to 50 grains of the ore are digested with hydrochloric acid, filtered and washed. The filtrate, concentrated if necessary by evaporation, is precipitated by great excess of chloride of barium. Every 100 parts of the sulphate of baryta produced indicate 34·37 parts of sulphuric acid. The insoluble residue on the filter is fused in a gold crucible with nitre and carbonate of soda, the fused mass is dissolved in hydrochloric acid, evaporated to dryness, moistened with strong acid, diluted and filtered; from the filtrate the sulphuric acid is precipitated as sulphate of baryta, every 100 parts of which indicate 13·748 parts of sulphur, and 25·48 parts of bisulphide of iron.

In the analysis of hæmatites it is necessary to bear in mind that perchloride of iron is partially reduced when boiled with finely divided iron pyrites and hydrochloric acid, sulphuric acid being formed.—*Dick.*

Phosphoric acid. — From 50 to 75 grains of the ore are digested with hydrochloric acid and filtered; the clear solution, which should not be too acid, is boiled with *sulphite of ammonia*, added gradually in small quantities till it either becomes colourless, or acquires a pale green colour, indicating that the peroxide of iron originally present has been reduced to protoxide; the solution is nearly neutralised with carbonate of ammonia, excess of acetate of ammonia added, and the liquid boiled; strong solution of perchloride of iron is then added drop by drop, until the precipitate which forms has a distinct red colour; this precipitate, which contains all the phosphoric acid originally present in the ore, is collected on a filter, washed, and redissolved in hydrochloric acid, tartaric acid added, and then ammonia. From this ammoniacal solution, the phosphoric acid is finally precipitated as ammonio-phosphate of magnesia, by the addition of chloride of ammonium, sulphate of magnesia, and ammonia. The precipitate is allowed 24 hours to subside, it is then collected on a filter, and if it has a yellow colour, which is almost invariably the case, it is redissolved in hydrochloric acid, and more tartaric acid being added, it is again precipitated by ammonia: 100 parts of the ignited pyrophosphate of magnesia correspond to 64·3 parts of phosphoric acid.

Alkalies. — It was ascertained by Mr. Dick, that nearly the whole of the alkali present in an iron ore are contained in that portion which is insoluble in hydrochloric acid. The residue from about 50 grains of the ore is placed in a platinum capsule, moistened with ammonia, and exposed for several hours to the action of hydrofluoric acid gas in a closed leaden dish; it may be necessary to repeat the operation if much silica is present; it is then slowly heated to dull redness, and dissolved in dilute hydrochloric acid; the solution is mixed with excess of baryta water and filtered; the excess of baryta is removed by carbonate of ammonia, and the solution is evaporated to dryness and ignited; the residue is redissolved in a little hot water, and a few drops of oxalate of ammonia added. If no precipitate or cloudiness occurs, it may be once more evaporated to dryness and gently ignited: the residue is chloride of potassium, 100 parts of which indicate 63 parts of potash. Should oxalate of ammonia have occasioned a precipitate, it must be filtered off, and the clear liquid evaporated. The search for potash is troublesome and lengthy; it may be altogether omitted in a technical analysis.

Determination of the remaining constituents. — 25 or 30 grains of the finely powdered ore are digested for about half an hour with strong hydrochloric acid, diluted with boiling distilled water and filtered. The residue on the filter being thoroughly washed, the solution is peroxidised, if necessary, by the addition of chlorate of potash, nearly neutralised by ammonia, boiled with excess of acetate of ammonia, and rapidly filtered while hot; the filtrate (which should be colourless) together with the washings, is received in a flask, ammonia is added, and then a few drops of bromine, and the flask closed with a cork. In a few minutes, if manganese be present, the liquid acquires a dark colour; it is allowed to remain at rest for 24 hours, then warmed, and rapidly filtered and washed; the brown substance on the filter is hydrated oxide of manganese: it loses its water by ignition, and then becomes $Mn^3 O^4$, 100 parts of which correspond to 93 parts of protoxide.

The liquid filtered from the manganese contains the *lime* and *magnesia*; the former is precipitated by oxalate of ammonia, and the oxalate of lime formed converted by ignition into carbonate, in which state it is either weighed, having been previously evaporated with carbonate of ammonia, or it is converted into sulphate by the addition of a few drops of sulphuric acid, evaporation, and ignition. The lime being separated, the magnesia is thrown down as ammonio-magnesian phosphate by phosphate of soda and ammonia, and after standing for 24 hours it is collected on a filter, washed with cold ammonia water, dried, ignited, and weighed; 100 parts of carbonate of lime correspond to 56·0 of lime; 100 parts of sulphate of lime to 40·1 of lime, and 100 parts of pyrophosphate of magnesia to 35·7 of magnesia.

The red precipitate collected on the filter after the boiling with acetate of ammonia, consists of the basic acetates of *iron* and *alumina*, together with the *phosphoric acid*. It is dissolved in a small quantity of hydrochloric acid, and then boiled in a silver or platinum basin with considerable excess of pure caustic potash; the alumina (with the phosphoric acid) is hereby dissolved, the insoluble portion is allowed to subside, and the clear liquid is then decanted, after which the residue is thrown on a filter and washed; the filtrate and washings are supersaturated with hydrochloric acid, nearly neutralised with ammonia, and the alumina finally precipitated by carbonate of ammonia. From the weight of the ignited precipitate, the corresponding amount of phosphoric acid determined by a separate operation is to be deducted, the remainder is calculated as *alumina*. The residue left after digesting the ore with hydrochloric acid, consists principally of *silica*, but it may also contain *alumina*, *peroxide of iron*, *lime*, *magnesia*, and *potash*. For practical purposes it is rarely necessary to submit it to minute examination; should such be desired, it must be dried, ignited, and weighed, then fused in a platinum crucible with four times its weight of mixed alkaline carbonates, the fused mass dissolved in dilute hydrochloric acid, and evaporated to dryness, the residue moistened with strong hydrochloric acid, and after standing at rest for some hours, digested with hot water, filtered, and the *silica* on the filter ignited and weighed. The *alumina*, *lime*, *oxide of iron*, and *magnesia* in the filtrate are separated from each other according to the instructions given above; the *potash* is estimated by a distinct process.

Carbonic acid. — This acid, which constitutes a considerable part of the weight of that large and important class of ores the *clay ironstones*, is estimated by noting the loss sustained after adding to a weighed portion of the ore sulphuric acid, and thus evolving the gas; or more roughly, by the loss sustained in the entire analysis. Another method is to fuse 20 or 25 grains of the ore with 60 or 80 grains of dry borax, and noting the loss, which consists of water and carbonic acid; by deducting the water obtained in a previous experiment, the quantity of carbonic acid is obtained. This method, however, can scarcely be recommended, on account of the corrosion of the crucible, though the results are very accurate.

Determination of the iron.—This is performed on a separate portion of the ore, either by the volumetric method of Marguerite, or by that of Dr. Penny: both give very exact results. Marguerite's method is based on the reciprocal action of the salts of protoxide of iron and permanganate of potash, whereby a quantity of the latter is decomposed exactly proportionate to the quantity of iron. The ore (about 10 or 15 grains) is dissolved in hydrochloric acid, and the metal brought to the minimum of oxidation by treating the solution with *sulphite of soda* (or better, *sulphite of ammonia*), and boiling to expel the excess of sulphurous acid; the solution of permanganate of potash is then cautiously added drop by drop, until the pink colour appears, and the number of divisions of the burette required for the purpose accurately noted. The solution should be considerably diluted, and there must be a sufficient quantity of free acid present to keep in solution the peroxide of iron formed and also the oxide of manganese. The whole of the iron must be at the *minimum* of oxidation, and the excess of sulphurous acid must be completely expelled; if the latter precaution be neglected an erroneous result will be obtained, as the sul-

phurous acid will itself take oxygen from the permanganic acid, and thus react in the same manner as iron.

To prepare the permanganate of potash, 7 parts of chlorate of potassæ, 10 parts of hydrate of potassa, and 8 parts of peroxide of manganese are intimately mixed. The manganese must be in the finest possible powder, and the potash having been dissolved in water, is mixed with the other substances, dried, and the whole heated to very dull redness for an hour. The fused mass is digested with water, so as to obtain as concentrated a solution as possible, and dilute nitric acid added till the colour becomes of a beautiful violet; it is afterwards filtered through asbestos. The solution must be defended from the contact of organic matter, and kept in a glass stoppered bottle. If the solution be evaporated it yields beautiful red acicular crystals: it is better to employ the crystals in the preparation of the test liquor, as the solution keeps much better when no *manganate* is present. To prepare the normal or test liquor, a certain quantity, say 15 grains, of piano-forte wire are dissolved in pure hydrochloric acid; after the disengagement of hydrogen has ceased, and the solution is complete, the liquor is diluted with about a pint of water, and accurately divided by measurement into two equal parts, the number of burette divisions of the solution of permanganate required to produce in each the pink colour is accurately noted; and this number is then employed to reduce into weight the result of the analysis of an ore. A useful normal liquor is made by dissolving 100 grains of the crystallised permanganate in 10,000 grains of water.

Penny's method is based on the reciprocal action of chromic acid and protoxide of iron, whereby a transference of oxygen takes place, the protoxide of iron becoming converted into peroxide, and the chromic acid into sesquioxide of chromium. The process is conducted as follows:— A convenient quantity of the specimen is reduced to coarse powder, and one half at least of this is still further pulverised until it is no longer gritty between the fingers. The test solution of bichromate of potash is next prepared: 44·4 grains of this salt in fine powder are weighed out, and put into a burette graduated into 100 equal parts, and warm distilled water is afterwards poured in until the instrument is filled to 0. The palm of the hand is then securely placed on the top, and the contents agitated by repeatedly inverting the instrument until the salt is dissolved and the solution rendered of uniform density throughout. Each division of the solution thus prepared contains 0·444 grains of bichromate, which Dr. Penny ascertained to correspond to half a grain of metallic iron. The bichromate must be pure, and should be thoroughly dried by being heated to incipient fusion. 100 grains of the pulverised iron-stone are now introduced into a Florence flask with 1½ oz. by measure of strong hydrochloric acid and ½ oz. of distilled water. Heat is cautiously applied, and the mixture occasionally agitated until the effervescence caused by the escape of carbonic acid ceases, the heat is then increased, and the mixture made to boil, and kept at moderate ebullition for ten minutes or a quarter of an hour. About 6 oz. of water are next added and mixed with the contents of the flask, and the whole filtered into an evaporating basin. The flask is rinsed several times with water, to remove all adhering solution, and the residue on the filter is well washed. Several small portions of a weak solution of *red* prussiate of potash (containing 1 part of salt to 40 water) are now dropped upon a white porcelain slab, which is conveniently placed for testing the solution in the basin during the next operation. The prepared solution of bichromate of potash in the burette is then added very cautiously to the solution of iron, which must be repeatedly stirred, and as soon as it assumes a dark greenish shade it should be occasionally tested with the red prussiate of potash. This may be easily done by taking out a small quantity on the end of a glass rod, and mixing it with a drop of the solution on the porcelain slab. When it is noticed that the last drop communicates a distinct blue tinge, the operation is terminated; the burette is allowed to drain for a few minutes, and the number of divisions of the test liquor consumed read off. This number multiplied by 2 gives the amount of iron per cent. The necessary calculation for ascertaining the corresponding quantity of protoxide is obvious. If the specimen should contain iron in the form of peroxide, the hydrochloric solution is deoxidised as before by sulphite of ammonia. The presence of peroxide of iron in an ore is easily detected by dissolving 30 or 40 grains in hydrochloric acid, diluting with water, and testing a portion of the solution with *sulphocyanide of potassium*. If a decided blood-red colour is produced, peroxide of iron is present. If it be desired to ascertain the relative proportions of peroxide and protoxide of iron in an ore, two operations must be performed: one on a quantity of the ore that has been dissolved in hydrochoric acid in a stout stoppered bottle; and another on a second quantity that has been dissolved as usual, and then deoxidised by sulphite of ammonia or by metallic zinc. It is advisable to employ the solution of bichromate much weaker than proposed by Dr. Penny, and to employ a burette graduated to cubic millimetres. A good strength is 1 grain of metallic iron = 10 cubic centimetres of bichromate.

Metals precipitable by sulphuretted hydrogen from the hydrochloric solution.—A weighed portion of the ore varying from 200 to 2000 grains is digested for a considerable time in hydrochloric acid: the solution is filtered off; the iron in the filtrate reduced when necessary by sulphite of ammonia, and a current of sulphuretted hydrogen passed through it. A small quantity of sulphur which is always suspended is collected on a filter and thoroughly washed; it is then incinerated at as low a temperature as possible. The residue (if any) is mixed with carbonate of soda and heated upon charcoal before the blowpipe: any globules of metal that may be obtained are dissolved and tested.

Analysis of pig iron.—The most important constituents to be determined are *carbon* (combined and uncombined), *silicon*, *sulphur*, *phosphorus*; those of less consequence, or of more rare occurrence, are *manganese*, *arsenic*, *copper*, *zinc*, *chromium*, *titanium*, *cobalt*, *nickel*, *tin*, *aluminum*, *calcium*, *magnesium*, and the *metals of the alkalies*.

1. *Determination of the total amount of carbon.*—About 100 grains of the iron in small pieces are digested, at a moderate temperature, in 6-oz. measures of a solution formed by dissolving 6 oz. of crystallised sulphate of copper, and 4 oz. of common salt in 20 oz. of water and 2 oz. of concentrated hydrochloric acid. The action is allowed to proceed until all, or nearly all the iron is dissolved. *Carbon* and *copper* are left insoluble; these are collected on a filter, and washed first with dilute hydrochloric acid (to prevent the precipitation of sub-chloride of copper), then with water, then with dilute caustic potash, and finally with boiling water. The mixed carbon and copper are dried on the filter, from which they are easily removed by a knife blade, and are mixed with oxide of copper, and burned in a combustion tube in the usual way, with a current of air, or, still better, of oxygen. The carbonic acid is collected in Liebig's apparatus, from which the amount of carbon is calculated.

2. *Graphite*, or *uncombined carbon.*—A weighed portion of the finely divided iron (filings or borings may be used) is digested with moderately strong hydrochloric acid, the combined carbon is evolved in combination with hydrogen, while the graphite is left undissolved. It is collected on a filter, washed, and then boiled with a solution of caustic potash, sp. gr. 1·27, in a silver dish; the silica which existed in the iron in the form of silicon is hereby dissolved; the clear caustic solution is drawn off by a pipe or syphon, and the black residue repeatedly washed; it is dried at as high a temperature as it will bear, and weighed; it is then heated to redness in a current of air, until the whole of the carbon is burnt off. A reddish residue generally remains, which is weighed, and the weight deducted from that of original black residue, the difference gives the amount of graphite.

3. *Silicon.*—The amount of this element is determined by evaporating to dryness a hydrochloric solution of a weighed quantity of the metal: the dry residue is re-digested with hydrochloric acid, diluted with water, boiled and filtered; the insoluble matter on the filter is washed, dried and ignited, until the whole of the carbon is boiled off; it is then weighed, after which, it is digested with solution of potash, and the residue, if any, washed, dried, ignited, and weighed: the difference between the two weights gives the amount of silicic acid, 100 parts of which indicate 47 parts of *silicon*.

Phosphorus.—A weighed portion of the metal is digested in nitro-hydrochloric acid, evaporated to dryness, and the residue re-digested with hydrochloric acid. The solution is treated precisely as recommended for the determination of phosphoric acid in ores; every 100 parts of pyrophosphate of magnesia indicate 28·56 parts of phosphorus.

Sulphur.—In *grey* iron this element is very conveniently and accurately estimated by allowing the gas evolved by the action of hydrochloric acid on a weighed quantity (about 100 grains) of the metal, in filings or borings, to pass slowly through a solution of acetate of lead acidified by acetic acid: the sulphur, the whole of which takes the form of sulphuretted hydrogen, enters into combination with the lead, forming a black precipitate of sulphide of lead, which is collected, washed, and converted into sulphate of lead by digesting it with nitric acid, evaporating to dryness, and gently igniting: 100 parts sulphate of lead = 10·55 sulphur. The most minute quantity of sulphur in iron is detected by this process. If, however, crude *white* iron is under examination, this method does not give satisfactory results, on account of the difficulty with which it is acted upon by hydrochloric acid; it is better, therefore, to treat the metal with nitro-hydrochloric acid, evaporate to dryness, re-digest with hydrochloric acid, and then precipitate the filtered solution with great excess of chloride of barium; or the finely divided metal may be fused in a gold crucible with an equal weight of pure nitrate of soda and twice its weight of pure alkaline carbonates; the fused mass is extracted with water acidified with hydrochloric acid, and finally precipitated by chloride of barium.

Manganese.—This metal is determined by the process described for its estimation in ores; the iron must exist in the solution in the form of sesquioxide.

Arsenic and copper.—The nitro-hydrochloric solution of the metal is evaporated to dryness, re-digested with hydrochloric acid, and filtered. The iron in the clear

solution is reduced to protochloride by boiling with a sufficient quantity of sulphite of ammonia, the solution is boiled till it has lost all smell of sulphurous acid. It is then saturated with sulphuretted hydrogen, and allowed to stand for 24 hours in a closed vessel, the excess of gas is boiled off, and the precipitate, if any, collected on a small filter and well washed; it is digested with monosulphide of potassium, which dissolves the sulphide of arsenic, leaving the sulphide of copper untouched; the latter is decomposed by heating with nitric acid, and the presence of copper evinced by the addition of ammonia, which produces a fine blue colour; the sulphide of arsenic is precipitated from its solution in sulphide of potassium by dilute sulphuric acid; it may be redissolved in *aqua regia*, and the nitric acid having been expelled by evaporation, the arsenic may be reduced in Marsh's apparatus.

Nickel and cobalt.—These metals, if present, will be found in the solution from which the copper and arsenic have been precipitated by sulphuretted hydrogen. The solution is peroxidised, and the sesquioxide of iron precipitated by slight excess of carbonate of baryta, after which the nickel and cobalt are precipitated by sulphide of ammonium.

Chromium and vanadium.—These metals which should be looked for in the carbonaceous residue obtained by dissolving a large quantity of the iron in dilute hydrochloric or sulphuric acid are detected as follows (*Wöhler*): — The ignited residue is intimately mixed with one-third of its weight of nitre, and exposed for an hour in a crucible to a gentle ignition. When cool, the mass is powdered and boiled with water. The filtered solution is gradually mixed and well stirred with nitric acid, taking care that it may still remain slightly alkaline, and that no nitrous acid is liberated which would reduce the vanadic and chromic acids. The solution is then mixed with an excess of solution of chloride of barium as long as any precipitate is produced. The precipitate, which consists of vanadiate and chromate of baryta, is decomposed with slight excess of dilute sulphuric acid, and filtered. The filtrate is neutralised with ammonia, concentrated by evaporation, and a fragment of chloride of ammonium placed in it. In proportion as the solution becomes saturated with chloride of ammonium, *vanadate* of ammonia is deposited as a white or yellow crystalline powder. To test for chromium only, the mass after fusion with nitre is extracted with water, and then boiled with carbonate of ammonia; the solution is neutralised with acetic acid, and then acetate of lead added; the production of a yellow precipitate indicates *chromic* acid.

Aluminium.—This metal is best separated from iron, by first reducing the latter to the state of protoxide by sulphite of ammonia, then neutralising with carbonate of soda, and afterwards boiling with excess of caustic potash, until the precipitate is black and pulverulent. The solution is then filtered off, slightly acidulated with hydrochloric acid, and the alumina precipitated by sulphide of ammonium.

Calcium and magnesium. — These metals are found in the solution from which the iron and aluminium have been separated; they both exist probably (together with the aluminium) in the cast iron in the form of *slag*, and are best detected in the black residue which is left on dissolving the iron in dilute sulphuric or hydrochloric acid. After digesting this residue with caustic potash, and burning away the graphite, a small quantity of a red powder is left, which is composed of silicic acid, oxide of iron, alumina, lime, and magnesia; if 500 grains of cast iron are operated upon, a sufficient quantity of insoluble residue will be obtained for a quantitative determination of its constituents. — H. M. N.

IRON-BRIDGE. See TUBES.

ISINGLASS (*Colle de Poisson*, Fr.; *Hausenblase*, Germ.), Ichthyocolla, *ἰχθυοκόλλα*, from *ἰχθύς*, a fish, and *κόλλα*, glue, or Fish glue, is a whitish, dry, tough, semi-transparent substance, twisted into different shapes, often in the form of a lyre, and consisting of membranes rolled together. Good isinglass is unchangeable in the air, has a leathery aspect, and a mawkish taste, nearly insipid; when steeped in cold water it swells, softens, and separates in membranous laminæ. At the boiling heat it dissolves in water, and the solution, on cooling, forms a white jelly, which is semi-transparent, soluble in weak acids, but is precipitated from them by alkalies. It is gelatine, nearly pure; and if not brittle, like other glue, this depends on its fibrous and elastic texture. The whitest and finest is preferred in commerce. Isinglass is prepared from the air-bladders of sturgeons, and especially the great sturgeon, the *Accipenser huso*, which is fished on the shores of the Caspian Sea, and in the rivers flowing into it, for the sake chiefly of its swimming bladder. It is also obtained from the *A. stellatus*, and the *A. Güldenstadtii*. We are informed that in Russia the *Siluris glanis* is also caught for the purpose of obtaining isinglass.

The preparations of isinglass in Russia, and particularly at Astracan, consists in steeping the swimming bladders in water, removing carefully their external coat, and the blood which often covers them, putting them into a hempen-bag, squeezing them, softening them between the hands, and twisting them into small cylinders. They are

ready for the market immediately after being dried in the sun, and whitened with the fumes of burning sulphur.

In some districts of Moldavia, another process is followed. The skin, the stomach, the intestines, and the swimming bladder of the sturgeon are cut in small pieces, steeped in cold water, and then gently boiled. The jelly thus obtained is spread in thin layers to dry, when it assumes the appearance of parchment. This being softened in a little water, then rolled into cylinders, or extended into plates, constitutes an inferior article.

The swimming bladder of the cod and many other fishes, also furnishes a species of isinglass, but it is much more membranous, and less soluble than that of the sturgeon.

The properties of isinglass are the same as those of gelatine or pure glue; and its uses are very numerous. It is employed in considerable quantities to clarify ale, wine, liqueurs, and coffee. As an article of food to the luxurious in the preparation of creams and jellies, it is in great request. Four parts of it convert 100 of water into a tremulous jelly, which is employed to enrich many soups and sauces. It is used along with gum as a dressing to give lustre to ribbons and other silk articles.

It is by covering thin silk with a coat of isinglass that court plaster is made. A solution of isinglass covered with carmine forms an excellent injection liquor to the anatomist. M. Rochen has made another pretty application of isinglass. He plunges into a limpid solution of it, made by means of a water-bath, sheets of wire gauze set in window or lamp frames, which, when cold, have the appearance of glass, and answer instead of it for shades and other purposes. If one dip be not sufficient to make a proper transparent plate of isinglass, several may be given in succession, allowing each film to harden in the interval between the dips. The outer surface should be varnished to protect it from damp air. These panes of gelatine are now generally used for lamps instead of horn, in the maritime arsenals of France. — See GELATINE.

Isinglass is known commercially as *Leaf isinglass*, *Long and short staple*, and *Book isinglass*. Dr. Royle speaks of the *Samovey leaf*, *book*, and *long and short staple*, in his paper *On the Production of Isinglass along the coasts of India, with a Notice of its Fisheries*. We receive from the Brazils, *Pipe*, *Lump*, and *Honeycomb Isinglass*.

Our *importations* of Isinglass in 1856 and 1857, were

Countries from which Imported.	Quantities.		Value.	
	1856.	1857.	1856.	1857.
	Cwts.	Cwts.	£	£
Russia	525	861	20,598	33,751
Prussia	166	- -	6.509	
Hanse Towns	47	21	1.838	235
Philippine Islands	48	35	388	327
Brazil	440	365	6,311	5,840
British East Indies	233	105	1,890	980
British Guiana	87	51	1,451	1,004
British N. America	- -	30	- -	415
Other parts	75	25	1,852	389
Totals	1621	1493	£40,837	£42,941

ISOMERISM, from *ισος*, equal, and *μερος*, part. Identity of elements and proportions with variations in physical properties. Thus, oil of turpentine and oil of citron are isomeric, each having the composition C^5H^4. The study of the laws of atomic constitution is one of the most important within the range of physico-chemical science, and beyond all others, it demands the highest powers of the philosopher, united with the mechanical care of the microscopic analyst. The tendency of science leads to the conviction that many of the bodies which we now regard as distinct elements are only isomeric; and such groups as chlorine, iodine, bromine, and fluorine, as sulphur, selenium, and boron, and as carbon and silicon, may with the advance of our knowledge be shown to be modified conditions of one form of matter. This subject will be fully treated in Ure's *Dictionary of Chemistry*.

ISOMORPHISM. Mitscherlich was the first to observe that many groups of substances, simple or compound, having an *analogous* constitution, crystallise in forms of the same crystalline character, or differ but little in their angles. Thus, *alumina*, *red oxide of iron*, and *oxide of chrome* crystallise in forms of the rhombohedral system.

Carbonate of lime, *carbonate of magnesia*, *protoxide of iron*, *protoxide of manganese*, and *oxide of lime* are also isomorphous forms belonging to the rhombohedral system.

Sulphate of barytes, *sulphate of strontia*, and *oxide of lead* crystallise in isomorphic forms of the prismatic system.

For a development of this law, consult Brooke and Miller's *Mineralogy*, and Dana's *System of Mineralogy*.

IVORY. (*Ivoire*, Fr.; *Elfenbein*, Germ.) The osseous matter of the tusks and teeth of the elephant, and of the tusks of the hippopotamus, and the horn of the narwhal.

From a valuable paper read by Professor Owen before the Society of Arts in December, 1856, we extract the following important notices on the growth and formation of ivory:—

"The substance of the teeth of other animals, beside the elephant, is an article of commerce. Formerly, the name ivory was given to the main substance of the teeth of all animals; but it is now, by the best anatomists and physiologists, restricted to that modification of *dentine*, or tooth substance, which, in transverse sections or fractures, shows lines of different colours, or striæ, proceeding in the arc of a circle, and forming by their decussation minute or curvilinear lozenge-shaped spaces. By this character, which is presented by every, the smallest portion of an elephant's tusk in transverse section or fracture, true ivory may be distinguished from every other kind of tooth substance, and from every counterfeit, whether derived from tooth or bone. It is a character,—this engine-turned decussatory appearance,—which is as characteristic of fossil as of recent ivory. Although, however, no other teeth except those of the elephant present the characteristics of true ivory, there are teeth in many other species of animals which, from their large size, and the density of their principal substance, are useful in the arts for purposes analogous to those for which true ivory is used; and some of those dental tissues, such as those of the large tusks of the hippopotamus, are more serviceable for certain purposes, especially in the manufacture of artificial teeth by the dentist, than any other kind of tooth-substance. The utility of teeth in commerce and in the arts, depends chiefly on a peculiar modification in their laws of growth. For the most part teeth, as in our own frames, having attained a certain size and shape, cease to grow. They are incapable of renewing the waste to which they are liable through daily use, and when worn away or affected by decay, they perish. Teeth of this kind are said to be of limited growth; but there are other teeth, such as the front teeth of the rat, rabbit, and all the rodent tribe, the tusks of the boar and hippopotamus, the long descending canine tusks of the walrus, the still longer spiral horn-like tusk of the narwhal, and the ivory tusks of the elephant, which are endowed with the property of perpetual growth; that is, they grow as long as the animal lives.

"In teeth of unlimited growth, fresh pulp, fresh capsule, and in some instances also fresh enamel organs are formed, and added to the pre-existing constituents of the tooth matrix, in proportion as those are calcified or converted into tooth substance; and as fast as the ivory and enamel may be worn away from the summit of such a tooth, will ivory and enamel be formed at its base, and thus the growth of the tooth is uninterrupted. The ratio of the addition of the formative principles is at first greater than the ratio of abrasion, and the tooth not only grows, but increases in size. When, however, the animal has attained its full growth, the tooth for the most part is reproduced without increase of size, or at most, augments only in length, and that in cases where its summit is not perpetually worn down by being opposed to that of an opposite tooth."

With respect to the distribution of the elephant, the same high authority has the following remarks:—

"In the present creation, elephants are restricted to the African and Asiatic continent. The African elephant, as is well known, is a distinct species from the Asiatic one; and some of the Asiatic elephants of the larger islands of the Indian Archipelago, as those of Sumatra, if not specifically distinct from the elephants of Continental Asia, form, at all events, a strongly marked variety. With reference, however, to the commercial relations of ivory, it is chiefly worthy of notice that in the Asiatic elephants, tusks of a size which gives them the value of ivory in commerce, are peculiar to the males, whilst in the African elephants, both males and females afford good-sized tusks, although there is a sexual difference of size in this species, those of the males being the largest. In former times, and, as it would seem, before man existed to avail himself of this beautiful animal substance for use or ornament, the large animals furnishing true ivory-proboscidian quadrupeds, as they are termed, from their peculiar prehensile nasal appendage, were much more widely spread over the globe and existed in far greater numbers than in the present day, more numerous in individuals, more numerous in species, manifesting so great diversities in the conformation of their grinding teeth, as to have led the naturalist and the palæontologist to divide them into two genera, called *Elephas* and *Mastodon*. A true elephant roamed in countless herds over the temperate and northern parts of Europe, Asia, and America. This was the creature called by the Russians, Mammoth; it was warmly clad with

both hair and fur, as became an animal deriving sustenance from the leaves and branches of trees, which grow as high as the 65th degree of north latitude. Some of the ivory of commerce is, or used to be, derived from the tusks of this extinct species."

The ivory of the tusks of the African elephant is most esteemed by the manufacturer for its density and whiteness.

The outside of the tusk of the elephant is covered by the cortical part, which is softer and less compact than the interior substance, with the exception of the brown plate that sometimes lines the interior cavity. The hardest, toughest, whitest, and most translucent ivory has the preference in the market; for many purposes the horn of the narwhal being considered the best. The horn of the narwhal is sometimes ten feet long.

The ivory of the hippopotamus is preferred by dentists; it is much harder than that of the elephant, its colour is a purer white, and it is almost free from grain. The teeth of the walrus, sometimes called the sea-cow, which hang perpendicularly from the upper jaw, are also used for the same purpose. The masticating teeth of some of the large animals are occasionally used as ivory; those of the spermaceti whale are of a flattened oval section, and resemble ivory in section, but they are dark coloured towards the centre, and surrounded by an oval band of white ivory.

Ivory has been used for ornamental works from the earliest periods. Phidias is stated to have been famous for his works made in ivory combined with gold, and described as the *Torentic Art*. The ivory statues of the ancients appear to have been formed upon centres, or cores of wood covered with plates of ivory.

In our days ivory has been extensively employed by the miniature painter; it is used by the turner in the manufacture of numberless useful and ornamental articles; the cutler makes his best knife handles from it; and the philosophical instrument maker constructs his scales from this material.

When ivory shows cracks or fissures in its substance, and when a splinter broken off has a dull aspect, it is reckoned of inferior value. Ivory is distinguishable from bone by its peculiar semi-transparent rhombohedral net-work, which may be readily seen in slips of ivory cut transversely.

Ivory is very apt to take a yellow-brown tint by exposure to air. It may be whitened or bleached, by rubbing it first with pounded pumice-stone and water, then placing it moist under a glass shade luted to the sole at the bottom, and exposing it to sunshine. The sunbeams without the shade would be apt to occasion fissures in the ivory. The moist rubbing and exposure may be repeated several times.

For etching ivory a ground made by the following recipe is to be applied to the polished surface:—Take of pure white wax, and transparent tears of mastic, each one ounce; asphalt, half an ounce. The mastic and asphalt having been separately reduced to fine powder, and the wax being melted in an earthenware vessel over the fire, the mastic is to be first slowly strewed in and dissolved by stirring; and then the asphalt in like manner. This compound is to be poured out into lukewarm water, well kneaded, as it cools, by the hand, into rolls or balls about one inch in diameter. These should be kept wrapped round with taffety. If white resin be substituted for the mastic, a cheaper composition will be obtained, which answers nearly as well; 2 oz. asphalt, 1 oz. resin, ½ oz. white wax, being good proportions. Callot's etching ground is made by dissolving with heat 4 oz. of mastic in 4 oz. of very fine linseed oil; filtering the varnish through a rag, and bottling it for use.

Either of these grounds being applied to the ivory, the figured design is to be traced through it in the usual way, a ledge of wax is to be applied, and the surface is to be then covered with strong sulphuric acid. The effect comes better out with the aid of a little heat; and by replacing the acid, as it becomes dilute by absorption of moisture, with concentrated oil of vitriol. Simple wax may be employed instead of the copperplate engravers' ground; and strong muriatic acid instead of sulphuric. If an acid solution of silver or gold be used for etching, the design will become purple or black on exposure to sunshine. The wax may be washed away with oil of turpentine. Acid nitrate of silver affords the easiest means of tracing permanent black lines upon ivory.

Ivory may be dyed by using the following prescriptions:—

1. *Black dye.*—If the ivory be laid for several hours in a dilute solution of neutral nitrate of pure silver, with access of light, it will assume a black colour, having a slightly green cast. A still finer and deeper black may be obtained by boiling the ivory for some time in a strained decoction of logwood, and then steeping it in a solution of red sulphate or red acetate of iron.

2. *Blue dye.*—When ivory is kept immersed for a longer or shorter time in a dilute solution of sulphate of indigo (partly saturated with potash), it assumes a blue tint of greater or less intensity.

3. *Green dye.*—This is given by dipping blued ivory for a little while in solution of nitro-muriate of tin, and then in a hot decoction of fustic.

4. *Yellow dye*—is given by impregnating the ivory first with the above tin mordant, and then digesting it with heat in a strained decoction of fustic. The colour passes into orange, if some Brazil wood has been mixed with the fustic. A very fine unchangeable yellow may be communicated to ivory by steeping it 18 or 24 hours in a strong solution of the neutral chromate of potash, and then plunging it for some time in a boiling hot solution of acetate of lead.

5. *Red dye*—may be given by imbuing the ivory first with the tin mordant, then plunging it in a bath of Brazil wood, cochineal, or a mixture of the two. Lac-dye may be used with still more advantage, to produce a scarlet tint. If the scarlet ivory be plunged for a little in a solution of potash, it will become cherry red.

6. *Violet dye*—is given in the logwood bath, to ivory previously mordanted for a short time with solution of tin. When the bath becomes exhausted, it imparts a lilac hue. Violet ivory is changed to purple-red by steeping it a little while in water containing a few drops of nitro-muriatic acid.

With regard to dyeing ivory, it may in general be observed, that the colours penetrate better before the surface is polished than afterwards. Should any dark spots appear, they may be cleared up by rubbing them with chalk; after which the ivory should be dyed once more to produce perfect uniformity of shade. On taking it out of the boiling hot dye bath, it ought to be immediately plunged into cold water, to prevent the chance of fissures being caused by the heat.

If the borings and chips of the ivory-turner, called ivory dust, be boiled in water, a kind of fine size is obtained.

Ivory made flexible.—Ivory articles may be made flexible and semi-transparent, by immersing them in a solution of pure phosphoric acid of sp. gr. 1·130, and leaving them there till they lose their opacity; they are then to be taken out, washed with water, and dried with a soft cloth; it thus becomes as flexible as leather. It hardens on exposure to dry air, but resumes its pliancy when immersed in hot water. Necks of children's sucking bottles are thus made.

It is not our intention to enter into the consideration of the handicrafts employing ivory, but a short account of the methods of preparing this beautiful material, which we extract from *Holtzapffel's Mechanical Manipulation*, will be of value.

"On account of the great value of ivory, it requires considerable judgment to be employed in its preparation, from three conditions observable in the form of the tusk; first, its being curved in the direction of its length; secondly, hollow for about half that extent, and gradually taper from the solid state to the thin feather edge at the root; and thirdly, elliptical or irregular in section. These three peculiarities give rise to as many separate considerations in cutting up the tooth with the requisite economy, as the only waste should be that arising from the passage of the thin blade of the saw: even the outside strips of the rind, called spills, are employed for the handles of penknives, and many other little objects; the scraps are burned in retorts for the manufacture of ivory black, employed for making ink for copper plate printers, and other uses, and the clean sawdust and shavings are sometimes used for making jelly.

"The methods of dividing the tooth, either into rectangular pieces or those of a circular figure required for turning, are alike in their early stages, until the lathe is resorted to. The ivory saw is stretched in a steel frame to keep it very tense; the blade generally measures from fifteen to thirty inches long, from one and a half to three inches wide, and about the fortieth of an inch thick; the teeth are rather coarse, namely, about five or six to the inch, and they are sloped a little forward, that is, between the angle of the common hand-saw tooth and the cross-cut saw. The instrument should be very sharp, and but slightly set; it requires to be guided very correctly in entering, and with no more pressure than the weight of its own frame, and is commonly lubricated with a little lard, tallow, or other solid fat.

"The cutter begins generally at the hollow, and having fixed that extremity parallel with the vice, with the curvature upwards, he saws off that piece which is too thin for his purpose, and then two or three parallel pieces to the lengths of some particular works, for which the thickness of the tooth at that part is the most suitable; he will then saw off one very wedge-form piece, and afterwards two or three more parallel blocks.

"In setting out the length of every section, he is guided by the gradually increasing thickness of the tooth; having before him the patterns or images of his various works, he will in all cases employ the hollow for the thickest work it will make. As the tooth approaches the solid form, the consideration upon this score gradually ceases, and then the blocks are cut off to any required measure, with only a general reference to the distribution of the *heel*, or the excess arising from the curved nature of the tooth, the cuts being in general directed as nearly as may be to the imaginary centre of curvature. The greater waste occurs in cutting up very long pieces, owing to the differ-

ence between the straight line and the curve of the tooth, on which account the blocks are rarely cut more than five or six inches long, unless for some specific object."

Mr. P. L. Simmonds has given the following as the weights of large elephants' tusks:—

Mr. Gordon Cumming had one weighing	173 lbs.
Mr. Cawood, of Graham's Town, had a pair weighing	330 lbs.
From Camaroon, shipped to Liverpool	164 lbs.
A tusk imported at Bristol	147 lbs.
At the Great Exhibition of 1851, tusk	162 lbs.

Imports of Ivory in the Years 1856 and 1857.

	Quantities.		Value.	
	1856.	1857.	1856.	1857.
TEETH—Elephants, sea cow, sea horse, or sea morse:—	Cwts.	Cwts.	£	£
Portugal	811	496	28,609	21,149
Tuscany	153	151	5,431	6,478
Egypt	828	1728	29,532	74,085
West Coast of Africa	1023	1132	36,382	48,527
United States	246	644	5,594	26,424
Malta	838	458	29,889	19,648
Sierra Leone	89	133	3,174	5,706
Gold Coast	91	-	3,246	
South Africa	579	1192	20,572	51,090
British East Indies	5027	3349	176,117	142,575
Other parts	181	529	4,971	22,290
Total	9866	9890	343,517	421,318

IVORY BLACK (*Noir d'ivoire*, Fr.; *Kohle von Elfenbein*, Germ.) is prepared from ivory dust, by calcination, in the very same way as is described under BONE BLACK. The calcined matter being ground and levigated on a porphyry slab affords a beautiful velvety black, much used in copperplate printing.

IVORY, FICTILE, is plaster of Paris which has been made to absorb, after drying, melted spermaceti, by capillary action, or it may be prepared according to Mr. Franchi's process as follows:— Plaster and colouring matter are employed in the proportions of a pound of superfine plaster of Paris to half an ounce of Italian yellow ochre. They are intimately mixed by passing them through a fine silk sieve, and a plaster cast is made in the usual way. It is first allowed to dry in the open air, and is then carefully heated in an oven; the plaster cast, when thoroughly dry is soaked for a quarter of an hour in a bath containing equal parts of white wax, spermaceti, and stearine, heated just a little beyond the melting point. The cast on removal is set on edge, that the superfluous composition may drain off, and before it cools, the surface is brushed, with a brush like that known by house painters as a sash tool, to remove any wax which may have settled in the crevices; and finally when the plaster is quite cold, its surface is polished by rubbing it with a tuft of cotton wool.

IVORY NUT. Corosos, or vegetable ivory. A species of the screw pine *Pandaneæ* growing in Central America and Columbia. The *Phytelephas macrocarpa* produces these nuts, which have a structure somewhat resembling that of ivory; but it more nearly resembles white wax. The ivory nut is not used for any important work.

J.

JACK, called also *jack in a box*, and *hand-jack*, is a portable, mechanical instrument, consisting of a rack and pinion, or a pair of claws and ratchet bar, moved by a winch handle, for raising heavy weights a little way off the ground.

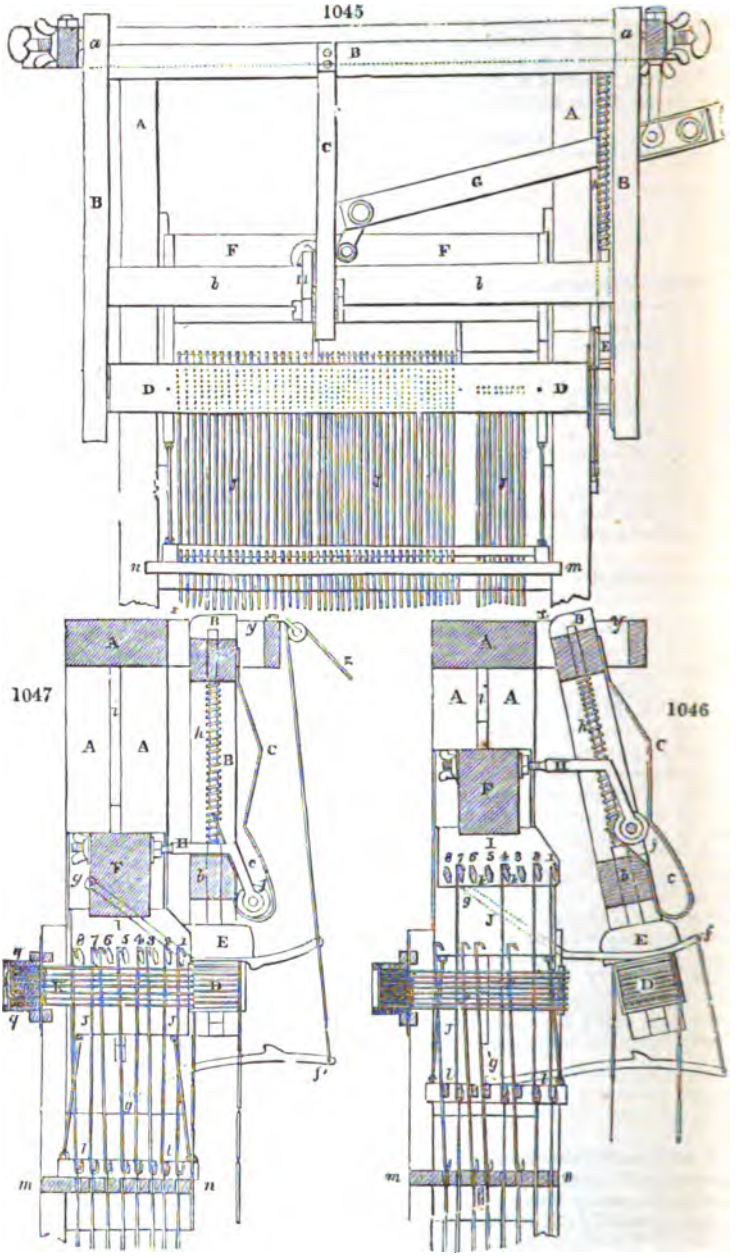
JACK and JACK-SINKERS, are parts of a stocking frame. See HOSIERY.

JACK-BACK, is the largest jack of the brewer.

JACK, BLACK. The miners' name for the sulphide (sulphuret) of zinc, or blende. See ZINC.

JACQUARD. A peculiar and most ingenious mechanism, invented by M. Jac-

quart of Lyons, to be adapted to a silk or muslin loom for superseding the employment of draw-boys, in weaving figured goods. Independently of the ordinary play of the warp threads for the formation of the ground of such a web, all those threads which



should rise simultaneously to produce the figure, have their appropriate healds, which a child formerly raised by means of cords, that grouped them together into a system, in the order, and at the time desired by the weaver. This plan evidently occasioned no

little complication in the machine, when the design was richly figured; but the apparatus of Jacquart, which subjects this manœuvre to a regular mechanical operation, and derives its motion from a simple pedal put in action by the weaver's feet, was generally adopted soon after its invention in 1800. Every common loom is susceptible of receiving this beautiful appendage. It costs in France 200 francs or 8*l.* sterling, and a little more in this country.

Fig. 1045 is a front elevation of this mechanism, supposed to be let down. *Fig.* 1046 is a cross section, shown in its highest position. *Fig.* 1047, the same section as the preceding, but seen in its lower position.

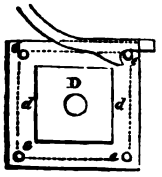
A, is the fixed part of the frame, supposed to form a part of the ordinary loom; there are two uprights of wood, with two cross-bars uniting them at their upper ends, and leaving an interval *x y* between them, to place and work the movable frame B, vibrating round two fixed points *a a*, placed laterally opposite each other, in the middle of the space *x y*, *fig.* 1045.

C is a piece of iron with a peculiar curvature, seen in front, *fig.* 1045, and in profile, *figs.* 1046 and 1047. It is fixed on one side upon the upper cross-bar of the frame B, and on the other, to the intermediate cross-bar *b* of the same frame, where it shows an inclined curvilinear space *c*, terminated below by a semicircle.

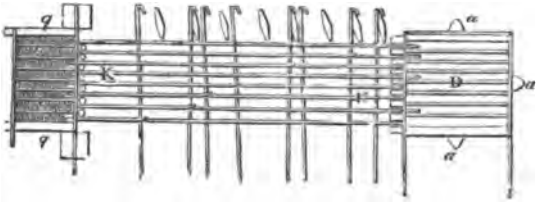
D is a square wooden axis, movable upon itself round two iron pivots, fixed into its two ends; which axis occupies the bottom of the movable frame B. The four faces of this square axis are pierced with three round, equal, truly-bored holes arranged in a quincunx. The teeth *a*, *fig.* 1049, are stuck into each face, and correspond to holes *a*, *fig.* 1052, made in the cards which constitute the endless chain for the healds; so that in the successive application of the cards to each face of the square axis, the holes pierced in one card may always fall opposite to those pierced in the other.

The right-hand end of the square axis, of which a section is shown in double size, *fig.* 1048, carries two square plates of sheet iron *d*, kept parallel to each other and a little apart, by four spindles *e*, passed opposite to the corners. This is a kind of lantern, in whose spindles, the hooks of the levers *f f'*, turning round fixed points *g g'* beyond the right hand upright A, catch hold, either above or below at the pleasure of the weaver, according as he merely pulls or lets go the cord *z*, during the vibratory movement of the frame B.

1048



1049



B is a piece of wood shaped like a T, the stem of which, prolonged upwards, passes freely through the cross-bar *b*, and through the upper cross-bar of the frame B, which serve as guides to it. The head of the T piece being applied successively against the two spindles *e*, placed above in horizontal position, first by its weight, and then by the spiral spring *h*, acting from above downwards, keeps the square axis in its position, while it permits it to turn upon itself in the two directions. The name *press* is given to the assemblage of all the pieces which compose the movable frame B B.

F is a cross-bar made to move in a vertical direction by means of the lever G, in the notches or grooves *i*, formed within the fixed uprights A.

H is a piece of bent iron, fixed by one of its ends with a nut and screw, upon the cross-bar F, out of the vertical plane of the piece C. Its other end carries a friction roller J, which, working in the curvilinear space *c* of the piece C, forces this, and consequently the frame B, to recede from the perpendicular, or to return to it, according as the cross-bar F is in the top or bottom of its course, as shown in *figs.* 1046 and 1047.

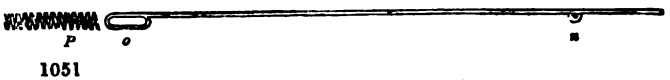
I, cheeks of sheet iron attached on either side to the cross-bar F, which serve as a safe to a kind of claw K, composed here of eight small metallic bars, seen in section *figs.* 1046 and 1047, and on a greater scale in *fig.* 1049.

J, upright skewers of iron wire, whose tops bent down hookwise naturally place themselves over the little bars K. The bottom of these spindles likewise hooked in the same direction as the upper ones, embraces small wooden bars *l*, whose office is to keep them in their respective places, and to prevent them from twirling round, so that the uppermost hooks may be always directed towards the small metallic bars

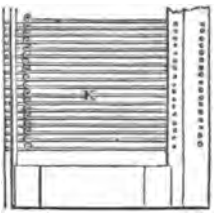
upon which they impend. To these hooks from below are attached strings, which after having crossed a fixed board *m n*, pierced with corresponding holes for this purpose, proceed next to be attached to the threads of the loops destined to lift the warp threads. K K, horizontal spindles or needles, arranged here in eight several rows, so that each spindle corresponds both horizontally and vertically to each of the holes pierced in the four faces of the square axis D. There are therefore as many of these spindles as there are holes in one of the faces of the square.

Fig. 1050 represents one of these horizontal spindles. *n* is an eyelet through which the corresponding vertical skewer passes. *o* another elongated eyelet, through which a small fixed spindle passes to serve as a guide, but which does not hinder it from moving lengthwise, within the limits of the length of the eyelet. *p*, small spiral springs placed in each hole of the case *q q*, *fig.* 1049. They serve the purpose of bringing back to its primitive position every corresponding needle as soon as it ceases to press upon it.

1050



1051



1052

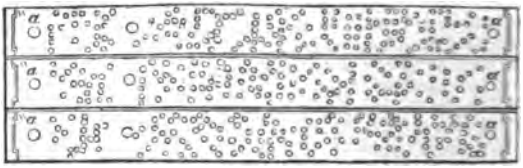


Fig. 1051 represents the plan of the upper row of horizontal needles. *Fig.* 1052 is a fragment of the endless chain, formed with perforated cards, which are made to circulate or travel by the rotation of the shaft D. In this movement, each of the perforated cards, whose position, form, and number, are determined by the operation of tying-up of the warp, comes to be applied in succession against the four faces of the square axis or drum, leaving open the corresponding holes, and covering those upon the face of the axis which have no corresponding holes upon the card.

Now let us suppose that the *press* B is let down into the vertical position shown in *fig.* 1047; then the card applied against the left face of the axis, leaves at rest or untouched the whole of the horizontal spindles (skewers), whose ends correspond to these holes, but pushes back those which are opposite to the unpierced part of the card; thereby the corresponding upright skewers, 3, 5, 6, and 8, for example, pushed out of the perpendicular, unhook themselves from above the bars of the claw, and remain in their place, when this claw comes to be raised by means of the lever C; and the skewers 1, 2, 4, and 7, which have remained hooked on, are raised along with the warp threads attached to them. Then by the passage across of a shot of the colour, as well as a shot of the common weft, and a stroke of the lay after shedding the warp and lowering the press B, an element or point in the pattern is completed.

The following card, brought round by a quarter revolution of the axis, finds all the needles in their first position, and as it is necessarily perforated differently from the preceding card, it will lift another series of warp threads; and thus in succession for all the other cards, which compose a complete system of a figured pattern.

This machine, complicated in appearance, and which requires some pains to be understood, acts however in a very simple manner. Its whole play is dependent upon the movement of the lever G, which the weaver himself causes to rise and fall, by means of a peculiar pedal; so that without the aid of any person, after the piece is properly read in and mounted, he can execute the most complex patterns as easily as he could weave plain goods; only attending to the order of his weft yarns, when these happen to be of different colours.

If some warp yarns should happen to break without the weaver observing them, or should he mistake his coloured shuttle yarns, which would so far disfigure the pattern, he must undo his work. For this purpose, he makes use of the lower hooked lever *f*, whose purpose is to make the chain of the card go backwards, while working the loom as usual, withdrawing at each stroke the shot both of the ground and of the figure. The weaver is the more subject to make mistakes, as the figured side of the web is downwards, and it is only with the aid of a bit of looking-glass that he takes a peep of his work from time to time. The upper surface exhibits merely loose threads in dif-

ferent points, according as the pattern requires them to lie upon the one side or the other.

Thus it must be evident, that such a number of paste-boards are to be provided and mounted as equal the number of throws of the shuttle between the beginning and end of any figure or design which is to be woven; the piercing of each paste-board individually will depend upon the arrangement of the lifting rods, and their connection with the warp, which is according to the design and option of the workman; great care must be taken that the holes come exactly opposite to the ends of the needles; for this purpose two large holes are made at the ends of the paste-boards, which fall upon conical points, by which means they are made to register correctly.

It will be hence seen, that, according to the length of the figure, so must be the number of paste-boards, which may be readily displaced so as to remount and produce the figure in a few minutes, or remove it, or replace it, or preserve the figure for future use. The machine, of course, will be understood to consist of many sets of the lifting rods and needles, shown in the diagram, as will be perceived by observing the disposition of the holes in the paste-board; those holes, in order that they may be accurately distributed, are to be pierced from a gauge, so that not the slightest variation shall take place.

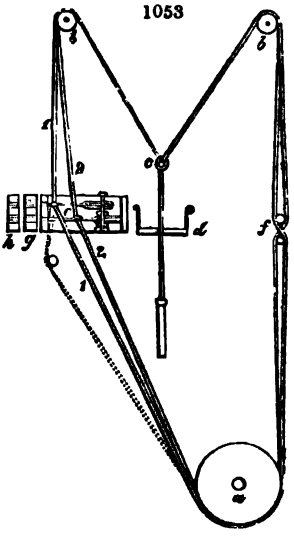
To form these card-slips, an ingenious apparatus is employed, by which the proper steel punches required for the piercing of each distinct card, are placed in their relative situations preparatory to the operation of piercing, and also by its means a card may be punched with any number of holes at one operation. This disposition of the punches is effected by means of rods connected to cords disposed in a frame, in the nature of a false simple, on which the pattern of the work to be performed is first read in.

These improved pierced cards, slips, or paste-boards, apply to a weaving apparatus, which is so arranged that a figure to be wrought can be extended to any distance along the loom, and by that means the loom is rendered capable of producing broad figured works; having the long lever *a* placed in such a situation that it affords power to the foot of the weaver, and by this means enables him to draw the heaviest morintures and figured works, without the assistance of a draw-boy.

The machinery for arranging the punches consists of a frame with four upright standards and cross-pieces, which contains a series of endless cords passing under a wooden roller at bottom, and over pulleys at the top. These pulleys are mounted on axles in two frames, placed obliquely over the top of the standard frame, which pulley-frames constitute the table commonly used by weavers.

In order better to explain these endless cords, *fig.* 1053 represents a single endless cord, 1 1, which is here shown in operation, and part of another endless cord, 2 2, shown stationary. There must be as many endless cords in this frame as needles in the weaving-loom. *a* is the wooden cylinder, revolving upon its axis at the lower part of the standards: *b b*, the two pulleys of the pulley-frames above, over which the individual endless cord passes; *c* is a small transverse ring. To each of these rings a weight is suspended by a single thread, for the purpose of giving tension to the endless cord. *d* is a board resembling a common comber-bar, which is supported by the cross-bars of the standard frame, and is pierced with holes, in situation and number corresponding with the perpendicular threads that pass through them; which board keeps the threads distinct from each other.

1053



At *e*, the endless cord passes through the eyes of wires resembling needles, which are contained in a wooden box placed in front of the machine, and shown in this figure in section only. These wires are called the *punch-projectors*; they are guided and supported by horizontal rods and vertical pins, the latter of which pass through loops formed at the hinder part of the respective wires. At *f* are two horizontal rods extending the whole width of the machine, for the purpose of producing the cross in the cords; *g* is a thick brass plate, extending along in front of the machine, and lying close to the box which holds the *punch-projectors*; this plate *g*, shown also in section, is called the *punch-holder*; it contains the same number of apertures as there are punch-projectors, and disposed so as to correspond with each other. In each of these apertures, there is a punch for the purpose of piercing the cards, slips, or pasteboards

with holes; *h* is a thick steel plate of the same size as *g*, and shown likewise in section, corresponding also in its number of apertures, and their disposition, with the punch-projectors and the punch-holder. This plate *h*, is called the *punch-receiver*.

The object of this machine is to transfer such of the punches as may be required for piercing any individual card from the punch-holder *g*, into the punch-receiver *h*; when they will be properly situated, and ready for piercing the individual card or slip with such holes as have been read in upon the machine, and are required for permitting the warp threads to be withdrawn in the loom, when this card is brought against the ends of the needles. The process of transferring the patterns to the punches will be effected in the following manner.

The pattern is to be read in, according to the ordinary mode, as in a false simple, upon the endless cords below the rods *f*, and passed under the revolving wooden cylinder *a*, to a sufficient height for a person in front of the machine to reach conveniently. He there takes the upper threads of the pattern, called the *heard*, and draws them forward so as to introduce a stick behind the cords thus advanced, as shown by dots, for the purpose of keeping them separate from the cords which are not intended to be operated upon. All the punch-projectors which are connected with the cords brought forward will be thus made to pass through the corresponding apertures of the punch-holder *g*, and by this means will project the punches out of these apertures, into corresponding apertures of the punch-receiver *h*. The punches will now be properly arranged for piercing the required holes on a card or slip, which is to be effected in the following manner.

Remove the punch-receivers from the front of the machine; and having placed one of the slips of card or pasteboard between the two folding plates of metal, completely pierced with holes corresponding to the needles of the loom, lay the punch-receiver upon those perforated plates; to which it must be made to fit by mortises and blocks, the cutting parts of the punches being downwards. Upon the back of the punch-receiver is then to be placed a plate or block, studded with perpendicular pins, corresponding to the above described holes, into which the pins will fall. The plates and the blocks thus laid together, are to be placed under a press, by which means the pins of the blocks will be made to pass through the apertures of the punch-receiver; and wherever the punch has been deposited in the receiver by the above process, the said punches will be forced through the slip of pasteboard, and pierced with such holes as are required for producing the figured design in the loom.

Each card being thus pierced, the punch-receiver is returned to its place in front of the machine, and all the punches forced back again into the apertures of the punch-holder as at first. The next set of cords is now drawn forward by the next *heard*, as above described, which sends out the *punch-projectors* as before, and disposes the punches in the punch-receiver, ready for the operation of piercing the next card. The process being thus repeated, the whole pattern is, by a number of operations, transferred to the punches, and afterwards to the cards or slips, as above described.

JADE, axe-stone (*Nephrite*, *Ceraunite*, Fr.; *Beilstein*, Germ.), is a mineral of a greenish, bluish, or whitish colour, compact, and of a fatty lustre. Spec. grav. 2·95; scratches glass; is very tough; fuses into a white enamel. It comes from China, and has been found in Australia; it is used among rude nations for making hatchets; and is susceptible of being cut into any form. In China the jade is greatly valued, especially the pure white varieties. These are worked into cups, and as ornaments for the Joo-e, or emblem of power.

The composition of jade, as given by Kastner and Raunuelsberg, is —

Silica	50·50	54·68
Magnesia	31·00	26·01
Lime		16·06
Protoxide of iron		2·15
Peroxide of iron	5·50	
Alumina	10·00	
Chromium	0·05	

H. W. B.

JAPAN EARTH; *Terra Japonica*. See GAMBIR.

JAPANNING is a kind of varnishing or lacquering, practised with excellence by the Japanese, whence the name.

The only difference between varnishing and japanning is that after the application of every coat of colour or varnish, the object so varnished is placed in an oven or stove at as high a temperature as can safely be employed without injuring the articles or causing the varnish to blister or run.

For black japanned works, the ground is first prepared with a coating of black, made by mixing dross ivory black to a proper consistence with dark coloured *amber* varnish, as this gives a blacker surface than could be produced by japan alone. If

the surface is required to be polished, five or six coats of japan are necessary to give sufficient body to prevent the japan from being rubbed through in polishing.

Coloured japans are made by mixing with some hard varnishes the required colour, and proceeding as described. See VARNISH.

JARGOON, the name given to a variety of Zircon from Ceylon. It is seldom perfectly transparent, and is either colourless or grey, with tinges of green, blue, red, and yellow of various shades, but generally smoky and ill-defined. It occurs in worn angular pieces, or in small detached crystals, rarely exceeding 6 or 8 carats in weight, chiefly in the sand of a river in Ceylon. The surfaces of the crystals are smooth, and possess a lustre more nearly approaching that of the diamond than any other gem. At the present day, though out of fashion and in no request, it is still occasionally sold for inferior diamonds.

Davy says that the light grey varieties of the zircon are sold by the inhabitants of Ceylon as imperfect diamonds, the natives being altogether ignorant of the true nature of the mineral. It is most abundant in the district of Matura, whence it has its common name in Ceylon of *Matura diamond*. The colourless zircon is also cut and sold as a false diamond in the bazaars of India. — H. W. B.

JASPER (*Jaspe calcedoine*, Fr.; *Jaspis*, Germ.) is a sub-species of quartz, of which there are five varieties. 1. The Egyptian red and brown, forming nodules with ring or tendril-shaped delineations. 2. Striped jasper, or clay altered by heat, and differing from true jasper by being fusible on the edges, before the blowpipe. 3. Porcelain riband or jasper. 4. Common jasper. 5. Agate jasper. The prettiest specimens are cut for seals, and for the inferior kinds of jewellery ornaments. See LAPIDARY. — H. W. B.

JATROPHA MANIHOT. A plant belonging to the Euphorbiaceæ, from which the *Cassava meal* is prepared, and from the express juice of which is obtained *Cassava starch* and *Tapioca*. See TAPIOCA.

JEAN. A twilled cotton, usually striped. Satin-jeans are woven so as to present a smooth glossy appearance. It is used for stays, &c.

JELLY, ANIMAL. See GELATINE, GLUE, and ISINGLASS.

JELLY, VEGETABLE. A great many vegetable productions yield upon infusion or decoction gelatinous solutions. These vary very much in character. The jelly of ripe currants and other berries, is a compound of mucilage and acid, which loses its power of gelatinising by prolonged ebullition.

JESSAMINE or JASMINE. A well-known family of plants. The *Jasmium fruticans*, a native of the southern parts of France, *J. odoratissimum*, a native of India, and *J. sumbac*, a native of India and Arabia, are used to obtain the essential oil of jasmine. See PERFUMERY.

JET. (*Jaiet*, or *jais*, Fr.) Jet occurs in the upper lias shale in the neighbourhood of Whitby, in Yorkshire, in which locality this very beautiful substance has been worked for many hundred years. The jet miner searches with great care the slaty rocks, and finding the jet spread out, often in extreme thinness between the laminations of the rock, he follows it with great care, and frequently he is rewarded by its thickening out to two or three inches.

The best jet is obtained from a lower bed of the upper lias formations. This bed has an average thickness of about 20 feet, and is known as jet rock. An inferior kind, known as soft jet, is obtained from the upper part of the upper lias, and from the sandstone and shale above it. The production of jet in this country appears to be limited to the coast of Yorkshire, from about nine miles south of Whitby to Boulby, about the same distance to the north; the estates of Lord Mulgrave being especially productive. There is a curious allusion to this in Drayton's Polyolbion.

> The rocks by Moultgrave, too, my glories forth to set,
> Out of their crannied rocks can give you perfect jet.

Dr. Young, in his Geology of the Yorkshire Coast, writes—"Jet, which occurs here in considerable quantities in the aluminous bed, may be properly classed with fossil wood, as *it appears to be wood in a high state of bituminisation*. Pieces of wood impregnated with silex are often found completely crusted with a coat of jet about an inch thick. But the most common form in which the jet occurs is in compact masses of from half an inch to two inches thick, from three to eighteen inches broad, and of ten or twelve feet long. The outer surface is always marked with longitudinal striæ, like the grain of wood, and the transverse fracture, which is conchoidal, and has a resinous lustre, displays the annual growth in compressed elliptical zones. Many have supposed this substance to be indurated *petroleum, or animal pitch*; but the facts now quoted are sufficient to prove its ligneous origin."

It does not appear to us that the "ligneous origin" of jet is by any means established; indeed we think the amount of evidence is against it. There is no example as far as we can learn, of any discovery of true jet having a strictly ligneous structure, or showing

anything like the conversion of wood into this coal-like substance. There appears, however, to have been some confusion in the observations of those who have written on the subject. Mr. Simpson, the intelligent curator of the Whitby museum, who has paid much attention to the subject, says, "Jet is generally considered to have been wood, and in many cases it undoubtedly has been so; for the woody structure often remains, and it is not unlikely that comminuted vegetable matter may have been changed into jet. But it is evident that vegetable matter is not an essential part of jet, for we frequently find that bone, and the scales of fishes also have been changed into jet. In the Whitby Museum there is a large mass of bone, which has the exterior converted into jet for about a quarter of an inch in thickness. The jetty matter appears to have first entered the pores of the bone, and there to have hardened; and during the mineralising process, the whole bony matter has been gradually displaced, and its place occupied by jet, so as to preserve its original form." After an attentive examination of this specimen, we are not disposed to agree entirely with Mr. Simpson.

Jet certainly incrusts a mass which has something the structure of a bone, but, without a chemical examination of its constituents, we should hesitate even to say it was bone. Wood without doubt has been found *encrusted* with jet, as fragments of animal matter may also have been. But it is quite inconsistent with our knowledge of physical and chemical changes, to suppose that both animal and vegetable matter would undergo this change. By *process of substitution*, we know that silica will take the place occupied by carbon, or woody matter; as, for example, in the fossil palms of Trinidad, and the silicified forests of Egypt; but we have no example within the entire range of the coal formations of the world of carbon taking the place of any of the earths.

Jet is found in plates, which are sometimes penetrated by belemnites. Mr. Ripley, of Whitby, has several curious examples, — two plates of jet, in one case enclose water-worn quartz pebbles; and in another jet partially invests an angular fragment of quartz rock. "This is the more remarkable," says Mr. Simpson, "as quartz rock, or, indeed, any other sort of rocky fragment, is rarely found in the upper lias."

The very fact that we find jet surrounding belemnites, casing adventitious masses of stone, and investing wood, seems to show, that a liquid, or at all events, a plastic condition, must at one time have prevailed. We have existing evidence of this. Dr. Young, in the work already quoted, says: — "In the cavities of nodules containing petrifactions, we sometimes meet with *petroleum*, or *mineral oil*. When first exposed, it is *generally quite fluid* and of a dark green colour; but it soon becomes viscid and black, and at last hardens into a kind of pitch, which generally melts with heat, and when ignited burns with a crackling noise, and emits a strong bituminous smell." One more sample of evidence in favour of the view that jet has been formed from wood. It is stated (*Reed's Illustrated Guide to Whitby*) that in front of the cliff-work of Haiburne Wyke existed a petrified stump of a tree, in an erect posture, three feet high, and fifteen inches across, having the roots of coaly jet in a bed of shale; whilst the trunk in the sandstone was partly petrified, and partly of decayed sooty wood. Even in this example it would appear, that after all, a coating of jet was all that really existed upon this example of the equisetum, which probably stands where it grew. Mr. Simpson, in a valuable little publication, "*The Fossils of the Yorkshire Lias described from Nature, with a short Outline of the Geology of the Yorkshire Coast*," says: — "From all we know respecting this beautiful mineral, it appears exceedingly probable that it has its origin in a certain bituminous matter, or petroleum, which abundantly impregnates the jet-rock; giving out a strong odour when it is exposed to the air. It is frequently found in a liquid state in the chambers of ammonites and belemnites and other cavities, and, whilst the unsuspicious operator is breaking a lias nodule, it flies out and stains his garment. This petroleum, or mineral oil, also occurs in nodules which contain no organic remains; and I have been informed by an experienced jet miner that such nodules are often associated with a good seam of jet, and are therefore regarded as an omen of success."

Jet is supposed to have been worked in this country long before the time of the Danes in England, for the Romans certainly used jet for ornamental purposes. Lionel Charlton, in the history of Whitby, says, that he found the ear-ring of a lady having the form of a heart, with a hole in the upper end for suspension from the ear, it was found in one of the Roman tumuli, lying close to the jaw bone. There exists no doubt that when the abbey of Whitby was the seat of learning and the resort of pilgrims, jet rosaries and crosses were common. The manufacture was carried on till the time of Elizabeth, when it seems to have ceased suddenly, and was not resumed till the year 1800, when Robert Jefferson, a painter, and John Carter made beads and crosses with files and knives:—a neck guard, made in this manner, fetched one guinea. A stranger coming to Whitby saw them working in this rude way, and advised them to try to turn it; they followed his advice and found it answer; several more then joined them, and

the trade has been gradually increasing since. Most of the best jet ornaments are sent to London, the inferior ones are mostly purchased for the American market.

The jet workers complain of the great scarcity of designs in jet. Several designs have been sent them, but the artists not being acquainted with the peculiarities of the material, their designs are not generally applicable, and the manufacturer is much more successful in the imitation of natural objects than any artificial combination.

JEWELLERY. See GEM and LAPIDARY.

JIGGING, *a mining term.* Separating the ore with a griddle, or wire-bottomed sieve, the heavier substances passing through to the bottom or lower part of the sieve, the lighter substance remaining on the upper part.

JINTA WAN. A substance somewhat resembling caoutchouc, imported from India.

JUJUBE. The fruit of the *Lizyphus vulgaris* and *L. jujuba*, about the size of and nearly resembling a small plum. The French confectioners prepare a lozenge from the juice of the fruit, but nearly all the jujubes sold by our druggists and confectioners are merely dried mucilage, flavoured and sweetened.

JUMPER, *a mining term.* A large borer, steeled at each end like chisel bits. It is worked by the hand.

JUNIPER. A genus of plants belonging to the order *Conifera*. About twenty species are known. This plant is cultivated mostly for its berries, which, when distilled with water, yield a volatile essential oil. The berries are largely employed in the manufacture of Hollands and gin. The French name of the plant is *Genevre*, and hence our English words "gin" and "geneva."

The *Juniperus Bermudiana*, the Bermuda red cedar, is a large tree with soft and fragrant wood, and is what is used in making pencils, and by cabinet makers. See CEDAR

JUTE consists of the fibres of two plants, called the chonch and isbund (*Corchorus olitorius* and *Corchorus capsularis*), extensively cultivated in Bengal, and forming, in fact, the material of which gunny bags and gunny cloth are made. It fetches nearly, though not quite so high, a price as sunn. See SUNN. It comes into competition with flax, tow, and codilla, in the manufacture of stair and other carpets, bagging for cotton and other goods, and such like fabrics, being extensively used for these purposes in Dundee. But it is unsuitable for cordage or other articles into which hemp is manufactured, from its snapping when twisted, and rotting in water.—*M'Culloch.*

K.

KABOOK. A name for a clay ironstone in Ceylon.—*Simmonds.*

KAL. "Wild iron; a coarse, false kind of iron" (*Borlase*). A mining term. In St. Just, in Cornwall, a *callan lode* is a lode containing much iron.

KALEIDOPHON. An instrument devised by Prof. Wheatstone. An elastic thin bar is fixed by one of its extremities, and at its free end it carries a silvered or polished ball; a ray of light is reflected from this ball, and when the thin plate is put in vibration, the fine point of light describes various curves, corresponding with the musical notes produced by the vibrations.

KALEIDOSCOPE. A well-known instrument invented by Sir David Brewster. It has been much employed in arts of design. The leading conditions are that the angle at which the reflectors are placed is a submultiple of 360°, that the only positions in which a body can be placed to form perfectly symmetrical images are between the ends of the mirrors, or in contact with the ends, and the eye must be as near as possible to the angular point.

KALI. The Arabs gave this name to an annual plant which grows near the seashore; now known under the name of *salsola soda*, and from whose ashes they extracted a substance, which they called *alkali*, for making soap. The term *kali* is used by German chemists to denote caustic potash; and *kalium*, its metallic basis; instead of our *potash* and *potassium*.

KANGAROO. A marsupial animal, native of Australia. Its tail makes excellent soup, and its skin, when tanned, becomes a soft and durable leather.

KAOLIN (*Terre à porcelaine*, Fr.; *Porzellanerde*, Germ.) is the name given by the Chinese to the fine white clay with which they fabricate the biscuit of their porcelains. See CLAY and PORCELAIN CLAY.

KARABE', a name of amber, of Arabic origin, in use upon the Continent.

KARN. A Cornish miner's term, frequently, according to Borlase, used to signify the solid rock;— more commonly a pile of rocks.

KARSTENITE. The name given by *Haus* to anhydrous sulphate of lime.

KATTIMUNDOO or CUTTEMUNDOO. A caoutchouc like substance obtained from the *Euphorbia antiquorum* of Roxburgh. It was first exhibited in this country in the Great Exhibition of 1851, being sent by Mr. W. Elliott from Vizagapatam.

It was of a dark brown colour, opaque except in thin pieces, hard and somewhat

brittle at common temperatures, but easily softened by heat. Perfectly insoluble in boiling water, but becoming soft, viscid, and remarkably sticky and adhesive like bird-lime, reassuming, as it cools, its original character.

It is said to be used for joining metal, fastening knife-handles, &c.

KEDGE ANCHOR. A small anchor with an iron stock used for warping.

KEELER. A manager of coal barges and colliers in the Durham and Northumberland district.

KEG. A cask containing five gallons.

KEEVE, *a mining term.* A large vat used in dressing ores: also a *brewer's term* for a mash tub.

KEIR. A boiler used in bleaching establishments. See BLEACHING.

KELP (*Varec*, F.; *Wareck*, Germ.) is the crude alkaline matter produced by incinerating various species of fuci, or *sea-weed.* They are cut with sickles from the rocks in the summer season, dried and then burned, with much stirring of the pasty ash. Dr. Ure analysed many specimens of kelp, and found the quantity of soluble matter in 100 parts of the best to be from 53 to 62, while the insoluble was from 47 to 38. The soluble consisted of —

Sulphate of soda	8·0	19·0
Soda in carbonate and sulphuret	8·5	5·5
Muriate of soda and potash	36·5	37·5
	53·0	62·0
The insoluble matter consisted of —		
Carbonate of lime	24·0	10·0
Silica	8·0	0·0
Alumina tinged with iron oxide	9·0	10·0
Sulphate of lime	0·0	9·5
Sulphur and loss	6·0	8·5
	100·0	100·0

The first of these specimens was from Heisker, the second from Rona, both in the Isle of Skye, upon the property of Lord Macdonald. From these, and many other analyses which were made by Dr. Ure, it appears that kelp is a substance of very variable composition, and hence it was very apt to produce anomalous results, when employed as the chief alkaline flux of crown glass, which it was for a very long period. The *Fucus vesiculosus* and *Fucus nodosus* are reckoned to afford the best kelp by incineration; but all the species yield a better product when they are of two or three years' growth than when cut younger. The *varec* made on the shores of Normandy contains almost no carbonate of soda, but much sulphate of soda and potash, some hyposulphite of potash, chloride of sodium, iodide of potassium, and chloride of potassium; the average composition of the soluble salts being, according to M. Gay-Lussac, 56 of chloride of sodium, 25 of chloride of potassium, and a little sulphate of potash. The very low price at which soda ash, the dry crude carbonate from the decomposition of sea salt, is now sold, has nearly superseded the use of kelp, and rendered its manufacture utterly unprofitable. When the common sea wrack, commonly used for producing kelp, is incinerated in a closed crucible it gives a charcoal termed *vegetable ethiops.*

KERMES GRAINS, ALKERMES, are the dried bodies of the female insects of the species *Coccus ilicis*, which lives upon the leaves of the *Quercus ilex* (prickly oak). Kirby and Spence, and also Stephens, state that the *Coccus ilicis* is found on the *Quercus coccifera.* The word *kermes* is Arabic, and signifies little worm. In the middle ages, this dye stuff was therefore called *vermiculus* in Latin, and vermeil and *vermilion* in French. It is curious to consider how the name *vermilion* has been since transferred to red sulphuret of mercury.

Kermes has been known in the East since the days of Moses; it has been employed from time immemorial in India to dye silk; and was used also by the ancient Greek and Roman dyers. Pliny speaks of it under the name of *coccigranum*, and says that there grew upon the oak in Africa, Sicily, &c., a small excrescence like a bud, called *cusculium*; that the Spaniards paid with these grains half of their tribute to the Romans; that those produced in Sicily were the worst; that they served to dye purple; and that those from the neighbourhood of Emerita in Lusitania (Portugal) were the best.

In Germany, during the ninth, twelfth, thirteenth, and fourteenth centuries, the rural serfs were bound to deliver annually to the convents a certain quantity of kermes, the *Coccus polonicus*, among the other products of husbandry. It was collected from the trees upon St. John's day, between eleven o'clock and noon, with religious ceremonies, and was therefore called *Johannisblut* (Saint John's blood), as also German cochineal. At the above period, a great deal of the German kermes was consumed in Venice, for dyeing the scarlet to which that city gives its name. After the discovery of America, cochineal having been introduced, began to supersede kermes for all brilliant red dyes.

The principal varieties of kermes are the *Coccus quercus*, the *Coccus polonicus*, the *Coccus fragariæ*, and the *Coccus uva ursi*.

The *Coccus quercus* insect lives in the south of Europe upon the kermes oak. The female has no wings, is of the size of a small pea, of a brownish-red colour, and is covered with a whitish dust. From the middle of May to the middle of June the eggs are collected, and exposed to the vapour of vinegar, to prevent their incubation. A portion of eggs is left upon the tree for the maintenance of the brood. In the department of the Bouches-du-Rhone, one half of the kermes crop is dried.

The kermes of Poland, or *Coccus polonicus*, is found upon the roots of the *Scleranthus perennis* and the *Scleranthus annuus*, in sandy soils of that country and the Ukraine. This species has the same properties as the preceding; one pound of it according to Wolfe, being capable of dyeing 10 pounds of wool; but Hermstaedt could not obtain a fine colour, although he employed 5 times as much of it as of cochineal. The Turks, Armenians, and Cossacks dye with kermes their morocco leather, cloth, silk, as well as the manes and tails of their horses.

The kermes called *Coccus fragariæ* is found principally in Siberia, upon the root of the common strawberry.

The *Coccus uva ursi* is twice the size of the Polish kermes, and dyes with alum a fine red. It occurs in Russia.

Kermes is found not only upon the *Lycopodium complanatum* in the Ukraine, but upon a great many other plants.

Good kermes is plump, of a deep red colour, of an agreeable smell, and a rough and pungent taste. Its colouring matter is soluble in water and alcohol; it becomes yellowish or brownish with acids, and violet or crimson with alkalies. Sulphate of iron blackens it. With alum it dyes a blood red; with copperas, an agate grey; with sulphate of copper and tartar, an olive green; with tartar and salt of tin, a lively cinnamon yellow; with more alum and tartar, a lilac; with sulphate of zinc and tartar, a violet. Scarlet and crimson dyed with kermes were called *grain colours*. The red caps for the Levant are dyed at Orleans with equal parts of kermes and madder, and occasionally with an addition of Brazil wood. Kermes is but little used in England at present as a dyeing substance.

KERMES MINERAL. Pure mineral kermes is regarded by Berzelius, Fuchs, and Rose, as an amorphous tersulphuret of antimony. As the preparation has no use in the arts or manufactures, for its mode of preparation and its chemical constitution we refer to *Ure's Dictionary of Chemistry*.

KERMESITE. Red antimony ore, composed of oxygen, 5·29; antimony, 74·45; sulphur, 20·49.

KERSEY. A coarse stuff woven from long wool, chiefly manufactured in the north of England.

KERSEYMERE. Commonly spelt cassimere. A fine fabric woven plain from the finest wools, a manufacture of the west of England principally.

KHAYA. One of the largest and handsomest trees growing on the western coast of Africa. The wood is of fine quality, and of a reddish colour like mahogany.

KIABOCCA WOOD, called also Amboyna wood. This wood is said to be the excrescence or burr of the *Pterospermum indicum*, or of the *Pterocarpus draco* from the Moluccas, the Island of Borneo, Amboyna, &c.

KIBBLE, *a mining term*. A bucket usually made of iron, in which the ore is drawn to the surface from the depths of the mine.

KILLAS. The name given by the Cornish miners to the *clay slate* of that district. It varies very much in colour and character, being sometimes of a clay-white, and at other times grey or blue. It is in one district soft; in another, compact and hard. According to the character of this rock, the miner determines on the probability of the mineral veins which traverse it being metalliferous or the contrary.

KILN (*Four*, Fr.; *Ofen*, Germ.) is the name given to various forms of furnaces and stoves, by which an attempered heat may be applied to bodies; thus there are brick-kilns, hop-kilns, lime-kilns, malt-kilns, pottery-kilns. See BRICK, LIMESTONE, MALT, POTTERY, for a description of their respective kilns.

KIMERIDGE CLAY. The sands which underlie the Portland Stone of Dorsetshire, and the south-west of England, are based upon a considerable thickness of dark brownish or bluish-grey clay, to which the term Kimeridge Clay has been given by geologists, from the circumstance of its being largely developed and well displayed in the neighbourhood of the village of that name.

Throughout the Isle of Purbeck, but especially in the part of it in question, the clay assumes a very shaly and bituminous character, sometimes passing into more massive beds of brownish shaly coal, possessing a conchoidal fracture.

The Romans, and also the Celts who inhabited the country previously to its invasion by the former nation, appear to have manufactured the harder portions of the

shale into cups and other articles, but, chiefly into beads, armlets, and bracelets, specimens of which last have been found in the neighbouring barrows, in some cases still encircling the wrists of skeletons.

Circular discs of shale, about the size of a penny piece, have also been dug up in great numbers in this part of the Isle of Purbeck: as many as 600 were, upon one occasion, found closely packed together.

Authorities have been much divided in opinion as to the origin and use of these circular pieces of shale; by some they are supposed to have passed current as money, or tokens, whence the name of Kimeridge coal-money, by which they are commonly known, has been applied to them; but, the most probable supposition is, that they were the portions of the material fixed to the lathe, and left adhering to it after the armlets or other ornaments of a similar description had been turned from their outer circumferences, and that at some subsequent period these refuse pieces of the turner were worn as amulets or charms by the superstitious.

The shale around Kimeridge abounds in animal and vegetable matter, the former consisting of the shells of oysters, ammonites, &c., together with the bones and teeth of large saurians and fish; while the latter is in so finely divided a state as not to be distinguishable to the eye. Much carbonate of lime and pyrites are also present, especially in those portions in which animal remains are most abundant.

The variation in the external character of the shale is accompanied by a corresponding variation in the relative proportions of mineral and organic matter contained in it; those portions which are the most fissile and slaty containing a large proportion of mineral matter combined with a relatively small proportion of organic matter; while on the other hand, in the harder and more massive portions which break with a conchoidal facture, the organic matter is greatly in excess of the mineral matter, as is shown by the following analyses.

	Greyish-green delicately fissile shale. A.		Brown shale with conchoidal fracture. B
Amount of volatile matter - - - -	19·51	52·8	73·3
" " mineral matter - - -	80·49	47·2	26·7
	100·00	100·0	100·0

When heated the shale gives off copious fumes of a disagreeable odour resembling that of petroleum; and when ignited, it burns of itself with a dull smoky flame, leaving, when freely exposed to the atmosphere, a reddish ash, which generally retains the form of the original fragment.

The shale has long been used for fuel by the people of the district where it occurs, and the ashes left after combustion have long been known to the farmers on the coast to exercise a beneficial influence upon their crops, especially turnips; but the unpleasant smell given out by it when burning has prevented it from being used except by the poorer inhabitants.

Within the last few years works were established at Wareham, for the purpose of extracting naphtha and other products from the shale by distillation; but the manufacture was abandoned in consequence of the impossibility of destroying the smell given out by the naphtha.

This defect having now, it is believed, been overcome, the works have lately been re-opened, and are now being carried on with every prospect of success.

The chemical composition and properties of the shale have been recently thoroughly investigated by Dr. Hofmann, of the Government School of Mines.

The following results were obtained by him from the distillation of the shale, at a high temperature, for the purpose of producing gas: —

Amount of gas, water, ammonia, &c. - - -	63·5
Amount of coke - - - - - - -	36·5—100·0

The shale distilled in a gas retort furnished a gas composed of: —

Olefiant gas and congeners - - - - -	8·8
Light carburetted hydrogen and hydrogen - -	69·3
Carbonic oxide - - - - - - -	9·7
Carbonic acid - - - - - - -	5·2
Sulphuretted hydrogen - - - - -	7·0—100·0

The composition of this gas, freed from carbonic acid and sulphuretted hydrogen, by passing through an ordinary lime purifier, was as follows: —

Olefiant gas and congeners	10·0
Light carburetted hydrogen and hydrogen	79·0
Carbonic oxide	11·0—100·0

The composition of the coke produced was: —

Carbon	73·4		72·8
Ash	34·3		30·3
	107·7		103·1

The excess above 100 arises from the presence of sulphides in the coal, which during the process of incineration absorb oxygen and are converted into sulphates.

A ton of shale furnished 11,300 cubic feet of this purified gas, the illuminating power of which, used in an argand burner, consuming 5 cubic feet per hour, equalled that of 20 sperm candles, while the percentage of coke remaining was 36·5.

The liquid and solid products obtained by the distillation of the shale at a low temperature, are an offensively smelling, dark brown oil, suspended in an aqueous liquid, charged with sulphuretted hydrogen, carbonic acid, and ammonia.

This oil, purified and distilled with water, furnishes an oily liquid heavier than water; a tar-like residue being left in the retort.

The oily liquid which, when purified, gives out the odour of the finest varieties of coal-gas naphtha, is a mixture of several chemical substances.

When treated with concentrated nitric acid, this oily liquid is divided into two portions, one of which is dissolved by the acid, while the other insoluble portion floats on the surface of the solution in the form of a light colourless oily liquid, resembling in its general character the hydrocarbons of Boghead coal-tar oil, and of petroleum. The nitric solution which forms the larger proportion of the oily liquid, when mixed with water, furnishes a dense, heavy, yellowish oil, with the odour of nitrobenzol.

Hence it appears that the oily liquid obtained by the distillation of the shale consists chiefly of benzol and its homologues, mixed with small quantities of petroleum hydrocarbons. When sufficiently purified it is applicable for all the purposes for which benzol is employed, for dissolving india-rubber and gutta-percha, for removing stains from fabrics, for preparing varnishes, for making artificial oil of almonds, &c.

On subjecting to distillation without water, and at a rather high temperature, the oily tar-like residue remaining in the retort after the crude volatile liquid obtained by heat from the shale had been distilled with water, other volatile products are obtained.

The first portion of the oil obtained during the distillation is of an amber colour when first distilled, and much less limpid than the oil produced by distillation with water. It also possesses an offensive sulphurous smell, which however is lost on exposure to the air, while the oil assumes a much darker colour. This oil is acted upon by sulphuric, nitric, and hydrochloric acids, by which, especially by the first, a portion of it is resinified.

The remaining portion of the oil, when washed with water and afterwards distilled with steam, furnishes a perfectly colourless oil with the properties of paraffine. This last oil, which forms but a small fraction of the original oil, behaves in all respects like the paraffine oil obtained from Boghead cannel coal, and is applicable to the lubrication of machinery, and all the other purposes to which that liquid is applied.

The black, pitch-like, coky residue left in the retort resembles in general character the coke produced from coal in the manufacture of gas.

The ash of the incinerated coke contains nearly the same proportions of silica, alumina, and iron as Portland cement. The following is an analysis of the ash left by the shale which contains the larger amounts of mineral matter: —

	Ash of Dorsetshire shale.	Portland cement.
Insoluble residue	29·01	
Peroxide of iron	7·10	5·30
Silica	21·75	22·23
Alumina	10·60	7·75
Lime	20·62	54·11
Carbonic acid	10·92	2·15
	100·00	

The distillation of the shale *at a low temperature*, for the purpos of obtaining the liquid and solid volatile products, furnished the following results : —

Analysis of A.

Coke	71·5	Mineral matter	54·1
		Carbon	15·0
		Hydrogen	2·4
Oily and solid volatile products	14·6	Light oil (naphtha)	2·7
		Heavy oil, containing 1·3 per cent. of paraffine	9·5
		Residue of pitch	2·4
Gas, water, ammonia, &c.	13·9	Gas, water, &c.	13·9
	100·0		100·0

Analysis of B.

Coke	43·0	Mineral matter	23·5
		Carbon	19·5
Oily and solid volatile products	39·0	Light oil (naphtha)	2·3
		Heavy oil, containing 1·9 per cent. of paraffine	36·7
Gas, water, &c.	18·0	Gas, water, ammonia, &c.	18·0
	100·0		100·0

The manufacture of the shale at Wareham, according to Mr. John C. Mansel, is conducted in the following manner : —

The retorts are charged with about 5 cwt. of shale, previously broken into pieces about two inches square, and the temperature is maintained as nearly uniform as possible. In order to obtain the required uniform temperature the retorts are constructed so as to have backs of molten lead. The gas formed in the retorts is then condensed by means of a leaden worm, and the product is a crude oil; a large quantity of gas is made during this operation, which is not condensed, but used for ordinary purposes. The crude oil is allowed to stand in long tanks for 48 hours, for the purpose of letting the ammoniacal water (of which there is a large quantity) subside. The oil is then put into a still, and rectified once or twice as the case may be. The first product is a light oil, making overproof 75°; the next products are heavy oils, containing paraffine, which is now in great request by manufacturers.

The shale, on being taken out of the retorts, is placed in close vessels, and when cool is ground in a mill for manure. In its unmanufactured state the shale is not sufficiently rich in ammonia for this purpose; but at this stage the artificial manure is as valuable as Ichaboe guano, both having been recently analysed for the purpose of comparison. By keeping the temperature low in the retorts neither the phosphates nor the organic matter are destroyed.

The name has been changed from Kimeridge shale to South Boghead coal by the manufacturers, the failure of the late company (by whom the former designation was used) having, it was considered, rendered the alteration expedient. The term South Boghead coal was selected from the resemblance to the Boghead coal of Scotland, now so extensively worked near Edinburgh.—H. W. B.

KING WOOD is imported from the Brazils, and is sometimes called violet wood. This is one of the most beautiful of the hard woods, and is used in small cabinet work.

KINIC ACID. A peculiar acid extracted by Vauquelin from cinchona.

KINO is an extract obtained most probably from the *Pterocarpus marsupium*, which grows on the Malabar coast. In India, kino is used for dyeing cotton a nankeen colour. It is of a reddish-brown colour, has a bitter styptic taste, and consists of tannin and extractive, 75 parts, and a red gum, 25 parts. It is used only as an astringent in medicine. Kino is often called a gum, but most improperly so.

KIP. A Malacca weight for tin, of 40 lbs. 11 oz. avoirdupoise. — *Simmonds.*

KIPS. The tanners call the skins of young animals kips.

KIRSCHWASSER, is an alcoholic liquor obtained by fermenting and distilling bruised cherries, called *kirschen* in German. The cherry usually employed in Switzerland and Germany is a kind of morello, which on maturation becomes black, and has a kernel very large in proportion to its pulp. When ripe, the fruit, being made to fall by switching the trees, is gathered by children, thrown promiscuously, unripe, ripe, and

rotten, into tubs, and crushed either by hand, or with a wooden beater. The mashed materials are set to ferment, and whenever this process is complete, the whole is transferred to a still, and the spirit is run off, by placing the pot over the common fireplace.

The fermented mash is usually mouldy before it is put into the alembic, the capital of which is luted on with a mixture of mud and dung. The liquor has accordingly, for the most part, a rank smell, and is most dangerous to health, not only from its own crude essential oil, but from the prussic acid derived from the distillation of the cherry-stones.

There is a superior kind of *kirschwasser* made in the Black Forest, prepared with fewer kernels, from choice fruit, properly pressed, fermented, and distilled.

KIRWANITE. A mineral found in basalt on the north-eastern coast of Ireland, consisting of silica, lime, alumina, and protoxide of iron.

KNIFE CLEANING MACHINES. Mr. Kent's machine for this purpose consists of a box or case, containing a couple of wooden discs, fixed near to each other upon a horozontal iron rod or spindle, which passes through the case, and is caused to rotate by means of a winch-handle. Each disc is, for about three-fourths of the area of its inner face, covered with alternate rows of bristles and strips of leather; and the remaining fourth part is covered with bristles only. The knife-blades to be cleaned are introduced through the openings in the case, between the rubbing surfaces of the discs; and rotatory motion being given to the discs by a winch-handle, the knives are rapidly cleaned and polished.

Mr. Masters constructed knife-cleaning machines upon the same plan as the above; but the rubbing surface of each disc is formed of strips of buff leather, with only a narrow circle of bristles around the edge of each surface, to clean the shoulders of the knives; small brushes are fixed beneath the holes in the case, through which the blades of the knives are inserted, to prevent the exit of dust from the apparatus.

Mr. Price has also devised a machine for cleaning knives, and another for cleaning forks. The knife-cleaner consists of a horizontal drum, covered with pieces of leather or felt, and fixed within another drum or circular framing, lined with leather or felt. The knives are introduced through openings, in a movable circular plate, at the front of the outer casing, and enter between the surfaces of the two drums. The plate is fixed upon a horizontal axis, which extends through the case, and is furnished at the back with a handle; by turning which the disc is caused to rotate and carry round the knives between the surfaces of the drums. The fork-cleaner consists of a box, with a long rectangular opening in the side; behind which two brushes are fixed, face to face. Between these brushes the prongs of the forks are introduced, and the handles are secured in a carrier, which is made to advance and recede alternately by means of a throw-crank, and thereby thrust the prongs into and draw them out of contact with the brushes. The carrier consists of two metal plates, the lower one carrying a cushion of vulcanised indiarubber for the fork handles to rest upon, and the upper being lined with leather; they are hinged together at one end, and are connected at the other, when the handles have been placed between them, by a thumb-screw.

KNOLLS. A mining term in Germany for lead ore separated from the smaller parts.

KNOPPERN are excrescences produced by the puncture of an insect upon the flower-cups of several species of oak. They are compressed or flat, irregularly pointed, generally prickly and hard; brown when ripe. They abound in Styria, Croatia, Sclavonia, and Natolia; those from the latter country being the best. They contain a great deal of tannin, are much employed in Austria for tanning, and in Germany for dyeing fawn, grey, and black. See GALLS.

KOUMISS is the name of a liquor which the Calmucks make by fermenting mare's milk, and from which they distil a favourite intoxicating spirit, called *rack* or *racky*.

The milk is kept in bottles made of hides till it becomes sour, is shaken till it casts up its cream, and is then set aside in earthen vessels, in a warm place to ferment, no yeast being required, though sometimes a little old koumiss is added. 21 pounds of milk put into the still afford 14 ounces of low wines, from which 6 ounces of pretty strong alcohol, of an unpleasant flavour, are obtained by rectification.

KOURIE WOOD. The wood of the New Zealand pine *Dammara Australis*, one of the most magnificent of the coniferous woods. It is also called *cowdie* and *kaurie* wood. It is much used for the masts of ships.

KRAMERIA. A shrub, which is a native of Peru, yielding the well-known rhatany root, often used as a dentifrice.

KREOSOTE, or CREOSOTE. One of the many singular bodies discovered by Reichenbach in wood tar. It derives its name from *χρέας* and *σώζω*, I preserve, in allusion to its remarkable antiseptic properties. A great deal of confusion exists in the published accounts of wood creosote, owing to the variable nature of the results obtained by the chemists who have examined it. This confusion is not found with that from coal, which undoubtedly contains two homologous bodies, $C^{12}H^5O^1$ and $C^{14}H^7O^2$; the first being carbolic, and the second cresylic acid. The composition of carbolic acid has long been

known, owing to the researches of Laurent: cresylic acid was recently discovered by Williamson and Fairlie. Commercial coal creosote sometimes consists almost entirely of cresylic acid. Coal oils, of very high boiling point, contain acids apparently homologues of carbolic acid, higher up in the series than even cresylic acid, and yet perfectly soluble in potash.—(*Greville Williams.*) There is little doubt that wood creosote consists essentially of the same substances as that from coal. The great difference in the odour arises chiefly from the fact of the product from coal retaining with obstinacy traces of naphthaline, parvoline, and chinoline, all of which are extremely odorous. No creosote found in commerce is ever perfectly homogeneous, nor, in fact, is it necessary that it should be so. If perfectly soluble in potash and acetic acid of the density 1·070, and if it does not become coloured by exposure to the air, it may be considered pure enough for all medicinal purposes. The oils from wood and coal tar may be made to yield creosote by the following process. The oils are to be rectified until the more volatile portions (which are lighter than water) have passed over. As soon as the product running from the still sinks in water the receiver is to be changed, and the oils may be received until the temperature required to send over the oil is as high as 480° F. The oil so obtained is to be dissolved in caustic soda, all insoluble in it being rejected. The alkaline solution, after being mechanically separated, as far as possible, from the insoluble oil, is to be boiled for a very short time. Two advantages are gained by this operation,—any volatile bases become expelled, and a substance which has a tendency to become brown on keeping, is destroyed. Sometimes the oil on treatment with potash yields a quantity of a crystalline paste. This is naphthaline, and should be removed by filtration through coarse calico or canvas. The alkaline liquid is then to be supersaturated with dilute sulphuric acid, on which the creosote separates and rises in the form of an oil to the surface. This creosote is already free from the greater number of impurities, and, if rectified, may be used for many purposes. To obtain a purer article the operations commencing with solution in caustic soda are to be repeated. If the alkaline solution on boiling again becomes coloured, the purification must be gone through a third time. It is essential not to boil the alkaline solution long, or a serious loss of creosote would take place. According to Reichenbach the boiling point of creosote is 397°. Carbolic acid boils between 369° and 370°. Cresylic acid boils at 397°. From this it would appear that Reichenbach's creosote consisted of cresylic acid. The specific gravity of creosote according to Reichenbach is 1·037 at 68°. That of carbolic acid is 1·065 at 64°. Carbolic acid and its homologues, when mixed with quicklime and exposed to the air, yield a beautiful red colour, owing to the formation of rosolic acid.—C. G. W.

KRYOLITE. See CRYOLITE.

KYANITE. A stone, which is sometimes blue and transparent. It is then employed as a gem; it resembles sapphire. Its chemical composition is, silica, 37·0; alumina, 63·0.

KYANOL. The old name of aniline. It was applied by Runge to the base from coal tar.—C. G. W.

KYROSITE. An arsenide of copper, from Briccius, near Annaberg.

L.

LABDANUM. A resin found on the leaves of the *Cistus Creticus*, in Candia. It is used in perfumery and for pastiles.

LABRADORITE. Opaline or Labrador felspar is a beautiful mineral, with brilliant changing colours, blue, red, and green, &c. Spec. grav. 2·70 to 2·75. Scratches glass; affords no water by calcination; fusible at the blowpipe into a frothy bead; soluble in muriatic acid; solution affords a copious precipitate with oxalate of ammonia. Cleavages of 93½° and 86½°; one of which is brilliant and pearly. Its constituents are, silica, 55·75; alumina, 26·5; lime, 11; soda, 4; oxide of iron, 1·25; water, 0·5.

Labradorite receives a fine polish, and the beauty of its chatoyant reflections recommends it as an article of ornament.—H. W. B.

LABURNAM. *Cytisus Laburnum.* (*Arbois Commun*, Fr.; *Goldregen*, Germ.) The wood of the laburnam tree is sometimes used in ornamental cabinet-work and in marquetry. "In the laburnam there is this peculiarity, namely, that the medullary plates, which are large and very distinct, are white, whereas the fibres are a dark brown, a circumstance which gives an extraordinary appearance to this wood."—*Aikin.*

LABYRINTH, in Metallurgy, means a series of canals distributed from the lead of a stamping-mill; through which canals a stream of water is transmitted for suspending, carrying off, and depositing, at different distances, the ground ores. See METALLURGY.

LAC. (*Laque*, Fr.; *Lack*, *Lackfarben*, Germ.) A resinous substance produced by the puncture of a peculiar female insect, called *Coccus lacca* or *ficus*, upon the branches of several plants; as the *Ficus religiosa*, the *Ficus Indica*, the *Rhamnus jujuba*, the *Croton lacciferum* or bihar tree, and the *Butea frondosa* or the pepel tree, which grow in Siam, Assam, Pegu, Bengal, and Malabar. The twig becomes thereby incrusted with a reddish mammillated resin, having a crystalline-looking fracture.

The female lac insect is of the size of a louse; red, round, flat, with 12 abdominal circles, a bifurcated tail, antennæ, and 6 claws, half the length of the body. The male is twice the above size, and has 4 wings; there is one of them to 5000 females. In November or December the young brood makes its escape from the eggs, lying beneath the dead body of the mother; they crawl about a little way, and fasten themselves to the bark of the shrubs. About this period the branches often swarm to such a degree with this vermin, that they seem covered with a red dust; in this case, they are apt to dry up, by being exhausted of their juices. Many of these insects, however, become the prey of others, or are carried off by the feet of birds, to which they attach themselves, and are transplanted to other trees. They soon produce small nipple-like incrustations upon the twigs, their bodies being apparently glued, by means of a transparent liquor, which goes on increasing to the end of March, so as to form a cellular texture. At this time the animal resembles a small oval bag, without life, of the size of cochineal. At the commencement, a beautiful red liquor only is perceived, afterwards eggs make their appearance; and in October or November, when the red liquor gets exhausted, 20 or 30 young ones bore a hole through the back of their mother, and come forth. The empty cells remain upon the branches. These are composed of the milky juice of the plant, which serves as nourishment to the insects, and which is afterwards transformed or elaborated into the red colouring matter that is found mixed with the resin, but in greater quantity in the bodies of the insects, in their eggs, and still more copiously in the red liquor secreted for feeding the young. After the brood escapes, the cells contain much less colouring matter. On this account, the branches should be broken off before this happens, and dried in the sun. In the East Indies this operation is performed twice in the year; the first time in March, the second in October. The twigs encrusted with the radiated cellular substance constitute the *stick-lac* of commerce. It is of a red colour more or less deep, nearly transparent, and hard, with a brilliant conchoidal fracture. The stick-lac of Siam is the best; it often forms an incrustation fully one quarter of an inch thick all round the twig. The stick-lac of Assam ranks next; and, last, that of Bengal, in which the resinous coat is scanty, thin, and irregular. There are three kinds of lac in commerce: stick-lac, which is the substance in its natural state, seed-lac, and shell-lac. According to the analysis of Dr. John, stick-lac consists, in 120 parts, of

An odorous common resin	80·00	Fatty matter, like wax	3·00
A resin insoluble in ether	20·00	Skins of the insects, and colouring matter	2·50
Colouring matter analogous to that of cochineal	4·50	Salts	1·25
Bitter balsamic matter	3·00	Earths	0·75
Dun yellow extract	0·50	Loss	4·75
Acid of the stick-lac (laccic acid)	0·75		120·00

According to Franke, the constituents of stick-lac are, resin, 65·7; substance of the lac, 28·3; colouring matter, 0·6.

Seed-lac.—When the resinous concretion is taken off the twigs, coarsely pounded, and triturated with water in a mortar, the greater part of the colouring matter is dissolved, and the granular portion which remains being dried in the sun, constitutes *seed-lac*. It contains of course less colouring matter than the stick-lac, and is much less soluble. Mr. Hatchett's analysis of seed-lac was as follows:—

Resin	68	Foreign bodies	6·5
Colouring matter	10	Loss	4
Wax	6		
Gluten	5·5		100

John found in 100 parts of it, resin, 66·7; wax, 1·7; matter of the lac, 16·7; bitter balsamic matter, 2·5; colouring matter, 3·9; dun yellow extract, 0·4; envelopes of insects, 2·1; laccic acid, 0·0; salts of potash and lime, 1·0; earths, 6·6; loss, 4·2.

Shell-lac.—In India the *seed-lac* is put into oblong bags of cotton cloth, which are held over a charcoal fire by a man at each end, and, as soon as it begins to melt, the bag is twisted so as to strain the liquefied resin through its substance, and, to make it drop upon smooth stems of the banyan tree (*Musa paradisa*). In this way, the resin spreads into thin plates, and constitutes the substance known in commerce by the name of *shell-lac*.

The Pegu stick-lac, being very dark coloured, furnishes a shell-lac of a corresponding deep hue, and therefore of inferior value. The palest and finest shell-lac is brought from the northern *Circar*. It contains very little colouring matter. A stick-lac of an intermediate kind comes from the Mysore country, which yields a brilliant lac-dye and a good shell-lac.

Shell-lac, by Mr. Hatchett's analysis, consists of resin, 90·5; colouring matter, 0·5; wax, 4·0; gluten, 2·8; loss, 1·8; in 100 parts.

The resin may be obtained pure by treating shell-lac with cold alcohol, and filtering the solution in order to separate a yellow grey pulverulent matter. When the alcohol is again distilled off, a brown, translucent, hard, and brittle resin, of specific gravity 1·139, remains. It melts into a viscid mass with heat, and diffuses an aromatic odour. Anhydrous alcohol dissolves it in all proportions. According to John, it consists of two resins, one of which dissolves readily in alcohol, ether, the volatile and fat oils; while the other is little soluble in cold alcohol, and is insoluble in ether and the volatile oils. Unverdorben, however, has detected no less than four different resins, and some other substances in shell-lac. Shell-lac dissolves with ease in dilute muriatic and acetic acids; but not in concentrated sulphuric acid. The resin of shell-lac has a great tendency to combine with salifiable bases; as with caustic potash, which it deprives of its alkaline taste.

This solution, which is of a dark red colour, dries into a brilliant, transparent reddish brown mass; which may be re-dissolved in both water and alcohol. By passing chlorine in excess through the dark-coloured alkaline solution, the lac-resin is precipitated in a colourless state. When this precipitate is washed and dried, it forms, with alcohol, an excellent pale-yellow varnish, especially with the addition of a little turpentine and mastic.

With the aid of heat, shell-lac dissolves readily in a solution of borax.

The substances which Unverdorben found in shell-lac are the following:

1. A resin, soluble in alcohol and ether;
2. A resin, soluble in alcohol, insoluble in ether;
3. A resinous body, little soluble in cold alcohol;
4. A crystallisable resin;
5. A resin, soluble in alcohol and ether, but insoluble in petroleum, and uncrystallisable.
6. The unsaponified fat of the *coccus* insect, as well as oleic and margaric acids.
7. Wax.
8. The *laccine* of Dr. John.
9. An extractive colouring matter.

Shell-lac is largely used in the manufacture of sealing wax and varnishes, and for japanning.

LAC-DYE, LAC LAKE, or *cake-lac*, is the watery infusion of the ground stick-lac, evaporated to dryness, and formed into cakes about two inches square and half an inch thick. Dr. John found it to consist of colouring matter, 50; resin, 25, and solid matter, composed of alumina, plaster, chalk, and sand, 22.

Dr. Macleod, of Madras, states that he prepared a very superior lac-dye from stick-lac, by digesting it in the cold in a slightly alkaline decoction of the dried leaves of the *Memecylon tinctorium* (perhaps the *M. capitellatum*, from which the natives of Malabar and Ceylon obtain a saffron yellow dye). This solution being used along with a mordant consisting of a saturated solution of tin in muriatic acid, was found to dye woollen cloth of a very brilliant scarlet hue.

The cakes of *lac-dye* imported from India, stamped with peculiar marks to designate their different manufacturers (*the best* DT, the second JMcR, the third CE), are now employed in England for dyeing scarlet cloth, and are found to yield an equally brilliant colour, and one less easily affected by perspiration than that produced by cochineal. When the lac-dye was first introduced, sulphuric acid was the solvent applied to the pulverised cakes, but as muriatic (hydrochloric) acid has been found to answer, it has to a great extent supplanted it. A good *solvent* (No. 1) for this dye-stuff may be prepared by dissolving 3 pounds of tin in 60 pounds of muriatic acid, of specific gravity 1·19. The proper *mordant* for the cloth is made by mixing 27 pounds of muriatic acid of sp. gr. 1·17, with 1½ pounds of nitric acid of 1·19; putting this mixture into a salt-glazed stone bottle, and adding to it in small bits at a time, grain tin, till 4 pounds be dissolved. This solution (No. 2) may be used within twelve hours after it is made, provided it has become cold and clear. For dyeing; three quarters of a pint of the solvent No. 1 is to be poured upon each pound of the pulverised lac-dye, and allowed to digest upon it for six hours. The cloth before being subjected to the dye bath, must be scoured in the mill with fuller's earth. To dye 100 pounds of pelisse cloth, a tin boiler of 300 gallons capacity should be filled nearly brimful with water, and a fire kindled under it. Whenever the temperature

rises to 150° Fahr., a handful of bran, and half a pint of the solution of tin (No. 2) are to be introduced. The froth, which rises as it approaches ebullition, must be skimmed off; and when the liquor boils, 10½ pounds of lac-dye, previously mixed with 7 pints of the solvent No. 1, and 3½ pounds of solution of tin No. 2, must be poured in. An instant afterwards, 10½ pounds of tartar, and 4 pounds of ground sumach, both tied up in a linen bag, are to be suspended in the boiling bath for five minutes. The fire being now withdrawn, 20 gallons of cold water, with 10½ pints of solution of tin being poured into the bath, the cloth is to be immersed in it, moved about rapidly during ten minutes; the fire is to be then re-kindled, and the cloth winced more slowly through the bath, which must be made to boil as quickly as possible, and maintained at that pitch for an hour. The cloth is to be next washed in the river; and lastly with water only, in the fulling mill. The above proportions of the ingredients produce a brilliant scarlet tint, with a slightly purple cast. If a more orange hue be wanted, white Florence argal may be used, instead of tartar, and some more sumach. Lac-dye may be substituted for cochineal in the orange-scarlets.

To determine the tinctorial power of lac-dye by comparison with proved samples, a dye-bath is prepared as follows:—5 grains of argal, 20 grains of flannel or white cloth, 5 grains of lac-dye, 5 grains of chloride of tin, 1 quart of water. Heat the water to the boiling point in a tin or china vessel; add thereto the argal, and then the piece of cloth or flannel. Weigh off 5 grains of the lac-dye and pulverise it in a Wedgewood mortar, with the 5 grains by measure of chloride of tin, and pour the whole into the hot liquor containing the cloth, taking care to rinse the mortar with a little of the hot liquor; keep the whole boiling for about half an hour, stirring the cloth or flannel about with a glass rod; then withdraw the cloth, wash and dry it for comparison. — *Normandy.*

In the former edition was a table of the imports and exports of lac-dye and lac-lake, which show that in 1802 only 253 lbs. were imported, which rose, however, in 1837, to 1,011,674 lbs.; the *imports*, &c., for the last three years being —

	1855.	1856.	1857.
	Cwts.	Cwts.	Cwts.
LAC-DYE:—			
British E. Indies	9,343	10,704	11,767
Other parts	81	271	429
	9,424	10,975	12,196
SHELL-LAC:—			
United States	722	- -	1,152
British E. Indies	20,822	13,847	18,399
Other parts	123	919	185
	21,667	14,766	19,736
SEED LAC	613	613	356
STICK LAC	5,595	1,151	2,665

LACCIC ACID crystallises, has a wine-yellow colour, a sour taste, is soluble in water, alcohol, and ether. It was extracted from stick-lac by Dr. John.

LACCINE is the portion of shell-lac which is insoluble in boiling alcohol. It is brown, brittle, translucid, consisting of agglomerated pellicles, more like a resin than anything else. It is insoluble in ether and oils. It has not been applied to any use.

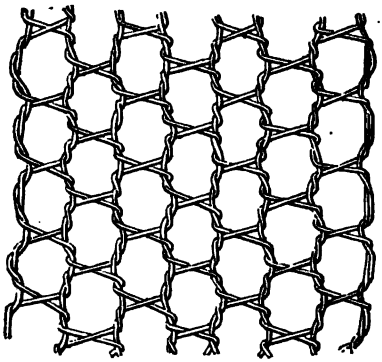
LACE BARK. The reticulated bark of the *Lagetta lintearia*. This splits into fibres, which resemble lace.

LACE MANUFACTURE. The pillow-made, or bone-lace, which formerly gave occupation to multitudes of women in their own houses, has, in the progress of mechanical invention, been nearly superseded by the bobbin-net lace, manufactured at first by hand-machines, but recently by the power of water or steam. Bobbin-net may be said to surpass every other branch of human industry in the complex ingenuity of its machinery; one of Fisher's spotting frames being as much beyond the most curious chronometer in multiplicity of mechanical device, as that is beyond a common roasting-jack. — *Ure.*

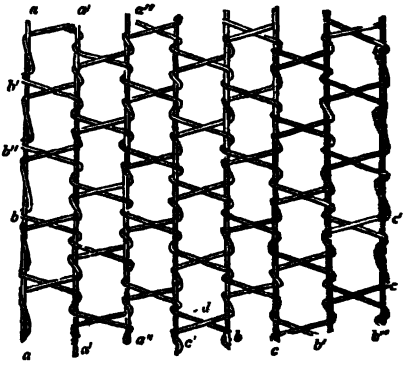
The threads in bobbin-net lace form, by their intertwisting and decussation, regular hexagonal holes or meshes, of which the two opposite sides, the upper and under, are directed along the breadth of the piece, or at right angles to the selvage or border. *Fig.* 1054 shows how, by the crossing and twisting of the threads, the regular six-sided mesh is produced, and that the texture results from the union of three separate sets of threads, of which one set proceeds downwards in serpentine lines, a second set proceeds from the left to the right, and a third from the right to the left, both in slanting

directions. These oblique threads twist themselves round the vertical ones, and also cross each other betwixt them, in a peculiar manner. This may be readily understood by examining the representation. In comparing bobbin-net with a common web, the perpendicular threads in the figure, which are parallel to the border, may be regarded as the warp, and the two sets of slanting threads as the weft.

1054



1055



These warp threads are extended up and down, in the original mounting of the piece between a top and bottom horizontal roller or beam, of which one is called the *warp beam*, and the other the *lace beam*, because the warp and finished lace are wound upon them respectively. These straight warp threads receive their contortion from the tension of the weft threads twisted obliquely round them alternately to the right and the left hand. Were the warp threads so tightly drawn that they became inflexible, like fiddle-strings, then the lace would assume the appearance shown in *fig.* 1055; and although this condition does not really exist, it may serve to illustrate the structure of the web. The warp threads stand in the positions *a a*, *a' a'*, and *a'' a''*; the one half of the weft proceeds in the direction *b b*, *b' b'*, and *b'' b''*; and the second crosses the first by running in the direction *c c*, or *c' c'*, towards the opposite side of the fabric. If we pursue the path of a weft thread, we find it goes on till it reaches the outermost or last warp thread, which it twists about; not once, as with the others, but twice; and then returning towards the other border, proceeds in a reverse direction. It is from this double twist, and by the return of the weft threads, that the selvage is made.

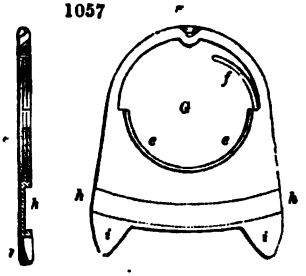
The ordinary material of bobbin-net is two cotton yarns, of from No. 180 to No. 250, twisted into one thread; but sometimes strongly twisted single yarn has been used. The beauty of the fabric depends upon the quality of the material, as well as the regularity and smallness of the meshes. The number of warp threads in a yard in breadth is from 600 to 900; which is equivalent to from 20 to 30 in an inch. The size of the holes cannot be exactly inferred from that circumstance, as it depends partly upon the oblique traction of the threads. The breadth of the pieces of bobbin-net varies from edgings of a quarter of an inch to webs 12 or even 20 quarters, that is, 2 yards wide.

Bobbin-net lace is manufactured by means of very costly and complicated machines, called *frames*. The limits of this Dictionary will admit of an explanation of no more than the general principles of the manufacture. The threads for crossing and twisting round the warp, being previously gassed, that is, freed from loose fibres by singeing with gas, are wound round small pulleys, called bobbins, which are, with this view, deeply grooved in their periphery. *Figs.* 1056, 1057, exhibit the bobbin alone, and with its carriage.

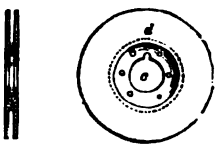
In the section of the bobbin *a*, *fig.* 1056, the deep groove is shown in which the thread is wound. The bobbin consists of two thin discs of brass, cut out in a stamp-press, in the middle of each of which there is a hollow space *c*. These discs are riveted together leaving an interval between their edge all round, in which the thread is coiled. The round hole in the centre, with the little notch at top, serves for spitting them upon a feathered rod, in order to be filled with thread by the rotation of that rod in a species of reel, called the bobbin-filling machine. Each of these bobbins (about double the size of the figure) is inserted into the vacant space *a* of the carriage, *fig.* 1057. This is a small iron frame (also double the size of the figure), which, at *e e*, embraces the grooved border of the bobbin, and by the pressure of the spring at *f*, prevents it from falling out. This spring serves likewise to apply sufficient friction to the bobbin, so as to prevent it from giving off its thread at *g* by its rotation,

unless a certain small force of traction be employed upon the thread. The curvilinear groove *h h*, sunk in each face or side of the carriage, has the depth shown in the sec-

1057

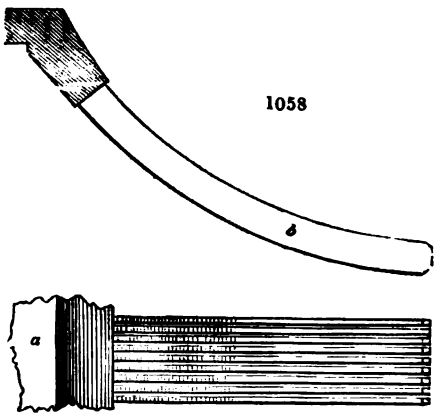


1056



tion at *h*. The groove corresponds to the interval between the teeth of the comb, or bars of the bolt, in which each carriage is placed, and has its movement. A portion of that bolt or comb is shown at *a*, *fig.* 1058 in plan, and one bar of a circular bolt machine at *b*, in section. If we suppose two such combs or bolts placed with the ends of the teeth opposite each other, but a little apart, to let the warp threads be stretched, in one vertical plane, between their ends or tips, we shall have an idea of the skeleton of a bobbin-net machine. One of these two combs, in the double bolt machine. has an occasional lateral movement called *shogging*, equal to the interval of one tooth or bolt, by which, after it has received the bobbins, with their carriages, into its teeth, it can shift that interval to the one side, and thereby get into a position to return the bobbins, with their carriages, into the next series of interstices or gates in the other bolt. By this means the whole series of carriages receives successive side steps to the right in one bolt, and to the left in the other, so as to perform a species of counter march, in the course of which they are made to cross and twist round about the vertical warp threads, and thus to form the meshes of the net.

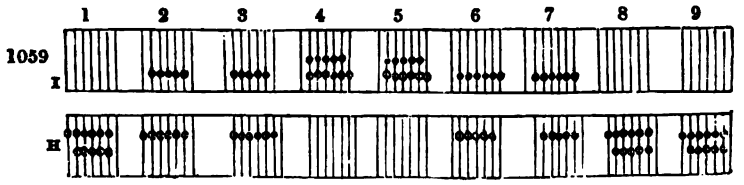
1058



The number of movements required to form a row of meshes in the double tier machine, that is, in a frame with 2 combs or bars, and 2 rows of bobbins, is six; that is, the whole of the carriages (with their bobbins) pass from one bar or comb to the other six times, during which passages the different divisions of bobbin and warp threads change their relative positions 12 times.

This interchange or traversing of the carriages with their bobbins, which is the most difficult thing to explain, but at the same time the most essential principle of the lace-machine, may be tolerably well understood by a careful study of *fig.* 1059, in which the simple line | represents the bolts or teeth, the sign ϕ the back line of carriages, and the sign ϕ the front line of carriages. H is the front comb or bolt bar, and I the back bolt

1059



bar. The former remains always fixed or stationary, to receive the carriages as they may be presented to it by the shogging of the latter. There must be always one odd carriage at the end; the rest being in pairs.

No. 1 represents the carriages in the front comb or bar, the odd carriage being at the left end. The back line of carriages is first moved on to the back bar 1, the odd carriage as seen in No. 1, having been left behind, there being no carriage opposite to drive it over to the other comb or bar. The carriages then stand as in No. 2. The bar 1 now shifts to the left, as shown in No. 3; the front carriages then go over into the back bar or comb, as is represented by No. 4. The bar 1 now shifts to the right, and gives the position No. 5. The front carriages are then driven over to the front bar, and leave the odd carriage on the back bar at the right end, for the same reason as before described, and the carriages stand as shown in No. 6. The bar 1 next shifts to the left, and the carriages stand as in No. 7 (the odd carriage being thereby on the back bar to the left). The back carriages now come over to the front bar, and stand as in No. 8. The back bar or comb 1 shifts to the right as seen in No. 9, which completes the traverse. The whole carriages with their bobbins have now changed their position, as will be seen by comparing No. 9 with No. 1. The odd carriage, No. 1, ϕ has advanced one step to the right, and has become one of the front tier; one of the back tier or line ϕ has advanced one step to the left, and has become the odd carriage; and one of the front ones ϕ has gone over to the back line. The bobbins and carriages throughout the whole width of the machine have thus crossed each other's course, and completed the mesh of net.

The carriages with their bobbins are driven a certain way from the one comb to the other, by the pressure of two long bars (one for each) placed above the level of the comb, until they come into such a position that their projecting heels or catches *i i*, *fig.* 1057, are moved off by two other long flat bars below, called the locker plates, and thereby carried completely over the interval between the two combs.

There are six different systems of bobbin-net machines. 1. Heathcoate's patent machine. 2. Brown's traverse warp. 3. Morley's straight bolt. 4. Clarke's pusher principle, single tier. 5. Leaver's machine, single tier. 6. Morley's circular bolt. All the others are mere variations in the construction of some of their parts. It is a remarkable fact, highly honourable to the mechanical judgment of the late Mr. Morley of Derby, that no machines except those upon his circular bolt principle have been found capable of working successfully by mechanical power.

The circular bolt machine (comb with curved teeth) was used by Mr. Morley for making narrow breadths or edgings of lace immediately after its first invention, and it has been regularly used by the trade for that purpose ever since, in consequence of the inventor having declined to secure the monopoly of it to himself by patent. At that time the locker bars for driving across the carriages had only one plate or blade. A machine so mounted is now called, "the single locker circular bolt." In the year 1824, Mr. Morley added another plate to each of the locker bars, which was a great improvement on the machines for making plain net, but an obstruction to the making of narrow breadths upon them. This machine is now distinguished from the former by the term "double locker."

A rack of lace, is a certain length of work counted perpendicularly, and contains 242 meshes or holes. Well-made lace has the meshes a little elongated in the direction of the selvage.

Mr. Heathcoate's machine, invented in 1809, was the first successful lace-making machine.

Mr. Morley patented his in 1811, and in the same year Messrs. Marl and Clarke invented the pusher machine, and Messrs. Leaver and Turton, of New Radford, brought forward the lever machine. In 1817, Mr. Heathcoate applied the rotatory movement to the circular bolt machine and mounted a manufactory at Tiverton on this plan, where the lace manufacture is still carried on extensively.

LACTIC ACID, $C^{12}H^{12}O^{12}$. *Syn.* Nanceic acid. (*Acide lactique*, Fr.; *Milchsäure*, Germ.) Discovered by Scheele in sour milk. Subsequently, M. Braconnot examined the sour liquid which floats above starch during its manufacture, also the acidified decoctions of various vegetables, including beet-root, carrots, peas, &c., and found an acid which he considered to be peculiar, and consequently named the nanceic. The acid formed under all these circumstances turns out to be the same; it is, in fact, lactic acid, which modern researches show to be a constant product of the fermentation of sugar, starch, and bodies of that class. The acidity of sauerkraut is due to the presence of the same substance. Liebig has recently extended and confirmed the experiments made many years ago by Berzelius, on the presence of lactic acid in the juice of flesh, but he denies its existence in urine, as asserted by MM. Cap and Henry, and others.

Preparation.—Lactic acid can be prepared easily in any quantity by the fermentation of sugar. Care must be taken, however, that the process does not go too far, because lactic acid undergoes with facility another decomposition, by which it becomes converted into butyric acid. The following process of M. Bensch for the preparation of lactate of lime can be recommended by the author of this article as yielding at a

small trouble and expense a very large quantity of product. In fact, he has prepared with facility upwards of three pints of butyric acid from lactate of lime obtained in this manner. Dissolve 6 lbs. of lump sugar, and half an ounce of tartaric acid in two gallons and a half of boiling water. Leave for a day or two, and then add two ounces of rotten cheese, and a gallon of skimmed milk stirred up with three pounds of well washed prepared chalk. The temperature should not fall below 86° F. nor rise above 95°. The water lost by evaporation must be made up by adding a little every few days. After a time, varying from ten days to a month, according to the temperature and other circumstances, the whole becomes a magma of acetate of lime. Two gallons of boiling water must then be added, and half an ounce of quicklime and the whole, after being boiled for half an hour, is to be filtered through a linen or flannel bag. The filtered liquid is to be evaporated until it begins to get somewhat syrupy, the fluid in this state being put aside to allow the salt to crystallise. The crystals, after being slightly washed with cold water, are to be recrystallised two or three times. To obtain lactic acid from the lactate of lime, it is necessary, in the first place, to convert the latter salt into that of zinc. For this purpose a crude lactic acid is first obtained thus: to every two pounds three ounces of lactate of lime dissolved in twice its weight of boiling water, seven ounces of oil of vitriol previously diluted with twice its volume of water are to be added. The boiling fluid is to be strained through a linen bag to remove the precipitate of gypsum, and the filtered liquid is to be boiled for 15 minutes with 8¾ ounces of carbonate of zinc. The boiling must not be continued longer, or a subsalt of sparing solubility would be produced. The liquid, which is to be filtered boiling, will deposit on cooling the lactate of zinc in colourless crystals, which are to be washed with a little cold water, and after being drained are to be dried by exposure to the air on frames covered with filtering paper. The mother liquid will yield a fresh quantity of lactate if it be boiled with the salt remaining on the filter and evaporated.

From the lactate of zinc the acid is to be separated by passing sulphuretted hydrogen through the solution of the salt in eight times its weight of boiling water. The gas is to be expelled by heat, and the fluid on evaporation yields pure syrupy lactic acid.

Lactic acid is a colourless syrupy liquid of a powerful pure acid taste. Its specific gravity is 1·215. It is bibasic, consequently the general formula for the lactates is $C^{12}H^{10}O^{10}$,2MO; M representing any metal.

The most important salts of lactic acid are those of zinc and lime. The former salt is that generally formed in examining animal or vegetable fluids with a view to the isolation of the acid. It is found with two different quantities of water according to the circumstances under which it is prepared, and it is worthy of remark that the amount of water of crystallisation remarkably affects the solubility of the salt in water and alcohol.

Lactic acid is produced from alanine by the action of nitrous acid according to the following equation:—

$$\underbrace{2C^6H^7NO^4}_{\text{Alanine.}} + 2NO^3 = \underbrace{C^{12}H^{12}O^{12}}_{\text{Lactic acid.}} + 4N + 2HO.$$

Anhydrous lactic acid, $C^{12}H^{10}O^{10}$, is produced by the action of heat on the syrupy acid. Lactic acid is considered by chemists to be constructed on the type of four atoms of water in which two atoms of hydrogen are replaced by the radical lactyl, thus:— $\left.\begin{matrix} C^{12}H^{10}O^8 \\ H^2 \end{matrix}\right\} O^4$.

The other two atoms of hydrogen are consequently basic. It has been said that lactic acid may, by fermentation, be converted into butyric acid; the following equation represents the metamorphosis:

$$\underbrace{C^{12}H^{12}O^{12}}_{\text{Lactic acid.}} = \underbrace{C^8H^8O^4}_{\text{Butyric acid.}} + 4CO^2 + 4H.$$

All the butyric acid employed for the preparation of butyric ether, or pine-apple essence, is now prepared by the fermentation of lactate of lime.—C. G. W.

LACQUER, is a varnish, consisting chiefly of a solution of pale shell-lac in alcohol, tinged with saffron, annotto, or other colouring matters. See VARNISH.

LACTOMETER is the name of an instrument for estimating the quality of milk, called also a *Galactometer*. The most convenient form of apparatus would be a series of glass tubes each about 1 inch in diameter, and 12 inches long, graduated through a space of 10 inches, to tenths of an inch, having a stopcock at the bottom, and suspended upright in a frame. The average milk of the cow being poured in to the height of 10 inches, as soon as the cream has all separated at top, the thickness of its

body may be measured by the scale; and then the skim-milk may be run off below into a hydrometer glass, in order to determine its density or relative richness in caseous matter, and dilution with water.

LACUSTRINE FORMATION (*a geological term*). Belonging to a lake.

LAKES. Under this general title is included all those pigments which are prepared by combining vegetable or animal colouring matter with earths or metallic oxides. The general method of preparation is to make an infusion of the substance, and to add thereto a solution of common alum; or sometimes, when it has been necessary to extract the colouring matter by the agency of an acid, a solution of alum saturated with potash. At first, a slight precipitate falls, consisting of alumina and the colouring matter; but if some alkali is added the precipitate is increased. Some colouring matters are brightened by alkalies; then the decoction of the dye-stuff is made in an alkaline liquor, and being filtered, a solution of alum is poured into it. Where the affinity of the colouring matter for the subsulphate of alumina is great, alumina recently precipitated is agitated with the decoction of the colouring body. The manufacture of lakes depends on the remarkable property possessed by alumina, of combining with and separating the organic colouring matters from their solutions.

Red Lakes.—The finest of these is CARMINE, which, as carminated lakes, called lake of Florence, Paris, or Vienna, is usually prepared by taking the liquor decanted from the carmine, and adding freshly precipitated alumina to it. The mixture is warmed a little, briskly agitated, and allowed to settle. Sometimes alum is dissolved in the decoction of cochineal, and then the alumina precipitated by potash; but the colour is not good when lakes are thus prepared, and to improve it the dyer's solution of tin is often added. A red lake may be prepared from kermes in a similar manner.

Brazil wood yields a red lake. The wood is boiled in a proper quantity of water for 15 minutes, and then alum and solution of tin being added, the liquor is to be filtered, and solution of potash poured in as long as it occasions a precipitate. This is separated by a filter, the powder well washed, and being mixed with a little gum water, made into cakes. Sometimes the Brazil wood is boiled with vinegar instead of water. An excess of potash produces a lake of a violet colour, and cream of tartar gives it a brownish hue.

Madder is much used in the preparation of lakes.

The following process is recommended: —

Diffuse two pounds of ground madder in four quarts of water, and after a maceration of 10 minutes strain and squeeze the grounds in a press. Repeat this maceration, &c., twice upon the same portion of madder. It will now have a fine rose colour. It must then be mixed with five or six pounds of water and half a pound of bruised alum, and heated upon a water-bath for 3 or 4 hours, with the addition of water, as it evaporates; after which the whole must be thrown on a filter cloth. The liquor which passes through is then to be filtered through paper, and precipitated by carbonate of potash. If potash be added in three successive doses, three different lakes will be obtained of diminishing beauty. The precipitates must be washed until the water comes off colourless, then with gum water made into cakes.

Yellow Lakes are made with decoctions of Persian or French berries, to which some potash or soda is added; into the mixture a solution of alum is to be poured so long as any precipitate falls. Quercitron will yield a yellow lake, provided the decoction is purified by either butter-milk or glue. Annotto lake is formed by dissolving this substance in a weak alkaline lye, and adding a solution of alum to the solution.

Lakes of other colours can be prepared in a similar manner; but true lakes of other colours are not usually manufactured.

LAMINABLE is said of a metal which may be extended by passing between steel or hardened (chilled) cast-iron rollers.

In the manufacture of rail and bar iron, laminated iron is rolled together at a welding heat, until the required bar or rail is formed (see RAILS). This is, even under the best possible circumstances, a defective manufacture. The union of the bars is never absolutely complete, and the result of the long-continued action of trains of carriages upon all rails is the development of the laminated plates, which frequently *peel* off, layer after layer, to the destruction of the rail, and to the great danger of the traveller. Railway iron should be rolled into form from perfectly homogeneous masses of metal. This lamination of iron rails has been laid hold of by those who advocate the hypothesis that the slate rocks owe their lamination to mechanical pressure, whereas it is evidently the result of an imperfect manufacture. See ROLLING MILLS.

LAMIUM ALBUM, or the dead nettle, is said by Leuchs to afford in its leaves a greenish-yellow dye. The *L. purpureum* dyes a reddish-grey with salt of tin, and a greenish tint with iron liquor.

LAMP-BLACK. Every person knows that when the combustion of oil in a lamp is imperfect it pours forth a volume of dense black soot. According to the quantity

of carbon contained in the material employed, so is the illuminating power of the flame produced by combustion. If, therefore, we have a very brilliant flame, and we subject it to any conditions which shall impede the progress of the combination of the carbon with the oxygen of the air, the result is at once the formation of solid carbon, or lamp-black. This is exhibited in a remarkable and often an annoying manner by the camphine lamp. If oil of turpentine, resin, pitch oil, or fat oil, be burnt in lamps under a hood, with either a rapid draught or an insufficient supply of air, the lamp-black collects on the hood, and is occasionally removed. Sometimes a metallic roller, generally of tin, is made to revolve in the flame, and rub against a brush. By the cooling influence of the metal, the heat of the flame is diminished, the combustion retarded, and the carbon deposited, and in the revolution of the cylinder swept off. Camphor burning forms a very beautiful black, which is sometimes used as a pigment.

The common varieties of lamp-black are made from all sorts of refuse resinous matters, and from the rejected fragments of pine trees, &c. In Germany, a long flue is constructed in connection with the furnace in which the resinous substances are burnt, and this flue communicates with a hood, composed of a loose woollen cloth, held up by a rope passing over a pulley. Upon this the soot collects, and is from time to time shaken down. In the best conducted manufactories about 3 cwt. of lamp black is collected in each hood in about twelve hours. In England, lamp-black is sometimes prepared from the refuse coking coal, or it is obtained in connection with coke ovens. The lamp-black, however, obtained from the combustion of coal or woody matter is never pure. See BONE BLACK, IVORY BLACK.

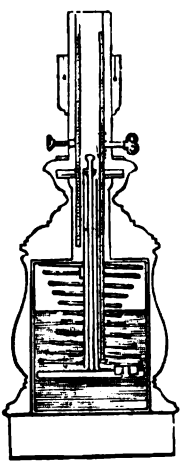
LAMP, DAVY. See SAFETY LAMP.

LAMPS. Under ILLUMINATION, will be found some notices of several kinds of lamps, with especial reference to the quantity of light produced by them.

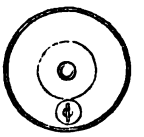
Lamps are very varied in form, and equally varied in the principles involved. A brief description, however, of a few of the modern varieties must suffice.

The moderator lamp. — The spiral spring has recently been introduced into the moderator lamps, for the purpose of forcing the oil up the wick of the lamp. This will be understood by the following description and drawings: — The distinguishing character of the moderator lamp is the direct transmission of the power, in the reservoir of oil, to the resistance offered by the weight of the column of oil, as it rises to the cotton; — and secondly, the introduction of a rectangular regulator, which equilibrates constantly by the resistance of the oil and the force applied to raise it. In the reservoir (*fig.* 1060), is a spiral spring which presses on the disc or piston, *fig.* 1061, which is furnished with a valve opening downwards. This spring is attached to a tooth rack, worked by a pinion wheel, by the means of which it is wound up. The mechanical force of the spring is equal to from 15 to 20 pounds; and as this force is exerted upon the disc, floating on the oil, this is forced up through the tube, and it overflows to the argand burner, thoroughly saturating the cotton, and supplying a constant stream of oil. This oil falls back into the reservoir, and is, of course, above the disc. When the spring has run down, it is again wound up; and then the valve opening downward allows the oil to flow back beneath the disc, to be again forced up through the tube. As the pressure employed is so great, the oil would, but for the "moderator," flow over with too much rapidity. This *moderator*, or regulator, is a tapering rod of iron-wire, which is placed in the ascending tube; and, as the pressure increases, it is forced more into it, and checks the flow of oil; whereas as it diminishes it falls, and being tapering, allows more oil to rise. Several ingenious adjustments are introduced into these lamps, as manufactured by the Messrs. Tylor of Warwick Lane, with which we need not at present deal. The cylinders containing the oil are covered with cases in metal or sometimes of porcelain. Two drawings of these are shown (*fig.* 1062 and *fig.* 1063). These lamps admit evidently of yet more elegant forms than have been given them. The urn-shaped, from the antique, in very pure taste, is the last introduction of the house above named.

1060



1061



It would be tedious to enumerate the various modifications of form and action to which the oil lamp has been subject, previous to its arrival at what may be deemed its perfect construction by Argand. The discovery of the mode of applying a new principle

by this individual not only produced an entire revolution in the manufacture of the article, but threatened with ruin all those whom the patent excluded from participation in the new trade; so much so indeed, that Argand, who had not been apprenticed to the business, was publicly persecuted by the tinners, locksmiths, and ironmongers, who disputed his right by any improvements to infringe the profits of their chartered vocation. "This invention," to quote a description of the lamp published some years ago, "embraces so many improvements upon the common lamp, and has become so general throughout Europe, that it may be justly ranked among the greatest discoveries of the age. As a substitute for the candle, it has the advantage of great economy and convenience, with much greater brilliancy; and for the purpose of producing heat, it is an important instrument in the hands of the chemist. We may, with some propriety," continues this authority, "compare the common lamp and the candle to fire made in the open air, without any forced method of supplying it with oxygen; while the Argand lamp may be compared to a fire in a furnace, in which a rapid supply of oxygen is furnished by the velocity of the ascending current. This, however, is not the only advantage of this valuable invention. It is obvious that, if the combustible vapour occupies a considerable area, the oxygen of the atmosphere cannot combine with the vapour in the middle part of the ascending column. The outside, therefore, is the only part which enters into combustion; the middle constituting smoke. This evil is obviated in the Argand lamp, by directing a current of atmospheric air through the flame, which, instead of being raised from a solid wick, is produced from a circular one, which surrounds the tube through which the air ascends."

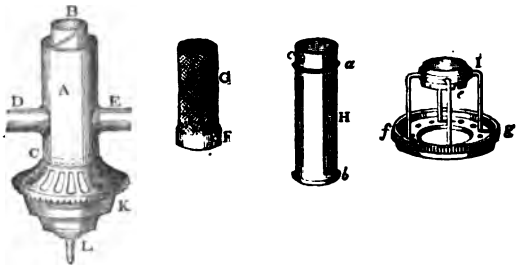
1062

1063

The mechanism of the Argand burner, in its present improved state, will be clearly understood from the annexed figures and explanation, which apply equally to each description of the lamps hereafter described.

A, *fig.* 1064, is a brass tube, about 3¼ inches in length, and 1¼ inch wide; within this tube is placed another, B, which is soldered fast inside by the flange at C: the space between these tubes contains the oil surrounding the wick, and which, being freely admitted from the reservoir by the side pipes D E, rises in the tubular space, either to a height corresponding with its level in the reservoir, or at least so as to maintain the wick in a state of constant saturation. The tube B is of considerable thickness, having a spiral groove cut about it from top to bottom: F is a metallic ring made to slip over the tube B; it contains a short pin inside, which fits exactly into the spiral groove just mentioned: G is the circular woven cotton wick, the lower end of which is drawn tight upon the neck of the ring; H is a copper tube, with a slit nearly from top to bottom: it admits the ring F, and being dropped over the inner tube B, exactly fits the inside of the wider tube A, by means of a narrow rim near the top at *a*, and another at the bottom *b*: between

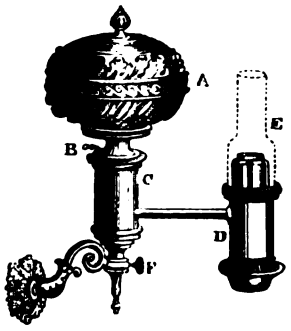
1064



the upper rim and the margin, there is a small projecting pin *c*, which, when the whole apparatus is combined, fits into the cavity *e* of the collar L. To prepare the lamp for use, the tube H is placed between A and B, as just described: the ring F, with its charge of cotton, is next inserted, the pin in the inside falling into the spiral groove, and that on the outside entering the slit in the tube H, which, on being turned about, moves the ring F down upon the screwed inner tube, until the wick only just rises above the superior edges of the tubes, in the interval between which it lies in the oil. In this stage, the frame I is placed on the nick in the collar at *e*, falling upon the pin near the top of H: the lower disc *f g*, passing over the tube A, at once presents a convenient support for the glass chimney, and a finger-hold for raising the wick. The central tube is open throughout, communicating, at its lower end, with the brass receptacle K; the latter is perforated at top, to admit the air which, by circulating through the above tube, and the hollow flame which surrounds it, causes the lamp to burn with that peculiar freedom and brilliancy which distinguish the Argand construction. This last-mentioned receptacle likewise catches any small quantity of oil which may pass over the inner tube during the combustion of the wick. L is the brass peg, which fits into the upper part of the pillar, in the table lamp.

In addition to the endless variety of small portable lamps, the peculiarities of which it would be tedious to particularise, and the merit of which, as compared with those on the Argand principle, consists, for the most part, in their cheapness, the more important articles, and those generally in demand, may be distinguished as fixed or bracket lamps, suspended or chandelier lamps, and table or French lamps — all these having burners on the principle above described. The former sort were, previous to the introduction of gas, very common in shops. The globe A (*fig.* 1065), which is sometimes made plain and

1065



1066

sometimes embossed, as in the cut, screws off, when the oil is poured in at an opening in the lower part, which is afterwards closed by means of a slide attached to the stem, B, and the globe, thus replenished, is inverted and screwed into the part, C. When the lamp is used, the stem B is raised a little, and the oil is suffered to flow through the intermediate tube into the cistern D, only at the rate at which it is consumed by the burning of the wick. The peculiar form of the glass chimney E is admirably calculated to assist in the more complete combustion of the matter drawn up to the wick when impure oil is used, a desideratum originally in part secured by placing over the central tube, and in the midst of the flame, a circular metal plate, by means of which the ascending column of air was turned out of its perpendicular course, and thrown immediately into that part of the flame where the smoke is formed, and which by this ingenious contrivance is effectually consumed; this application, however, is not necessary, nor the form of much moment, when purified sperm oil is used. These lamps being usually made to move on a pivot at F, attached to the wall or other support, are very convenient in many situations, as being easily advanced over a desk or counter, and afterwards turned aside, when not in use.

The sinumbral lamp having passed out of use need not be described.

The use of spirit lamps followed, and we have the naphtha and camphine lamps of this order. The accompanying woodcut (*fig.* 1066) shows the peculiarity of the camphine lamp where the reservoir of spirit (turpentine deprived of smell) is far below the burner, to which it ascends by capillary attraction, through the tubes of the cotton wick. Lamps to burn naphthas (*Belmontine*, &c.) are constructed on the same principle.

One of the best oil lamps, is that known as Carcel's lamp.

In this lamp the oil is raised through tubes by clock-work, so as continually to overflow at the bottom of the burning wick; thus keeping it thoroughly soaked, while the excess of the oil drops back into the cistern below. I have possessed for several years an excellent lamp of this description, which performs most satisfactorily; but it can hardly be trusted in the hands of a servant; and when it gets at all deranged, it must be sent to its constructor in Paris to be repaired. The light of this lamp, when furnished with an appropriate tall glass chimney, is very brilliant, though not perfectly uniform; since it fluctuates a little, but always perceptibly to a nice observer, with the alternating action of the pump-work; becoming dimmer after every successive jet of oil, and brighter just before its return. The flame, moreover, always flickers more or less, owing to the powerful draught, and rectangular reverberatory shoulder of the chimney. The mechanical lamp is, however, remarkable for continuing to burn, not only with unabated but with increasing splendour for 7 or 8 hours; the vivacity of the combustion increasing evidently with the increased temperature and fluency of the oil, which by its ceaseless circulation through the ignited wick, gets eventually pretty warm. In the comparative experiments made upon different lights by the Parisian philosophers, the mechanical lamp is commonly taken as the standard. I do not think it entitled to this pre-eminence: for it may be made to emit very different quantities of light, according to differences in the nature and supply of the oil, as well as variations in the form and position of the chimney. Besides, such lamps are too rare in this country to be selected as standards of illumination.

The following experiments by Dr. Ure, are well worth preserving.

The great obstacle to the combustion of lamps lies in the viscidity, and consequent sluggish supply of oil, to the wicks; an obstacle nearly insuperable with lamps of the common construction during the winter months. The relative viscidity or relative fluency of different liquids at the same temperature, and of the same liquid at different temperatures, has not, I believe, been hitherto made the subject of accurate researches. I was, therefore, induced to make the following experiments with this view.

Into a hemispherical cup of platinum, resting on the ring of a chemical stand, I introduced 2000 water-grain measures of the liquid whose viscidity was to be measured, and ran it off through a glass siphon, $\frac{1}{8}$ of an inch in the bore, having the outer leg $3\frac{1}{2}$ inches, and the inner leg 3 inches long. The time of efflux became the measure of the viscidity; and of two liquids, if the specific gravity and consequent pressure upon the siphon were the same, that time would indicate exactly the relative viscidity of the two liquids. Thus, oil of turpentine and sperm oil have each very nearly the same density; the former being, as sold in the shops, = 0·876, and the latter from 0·876 to 0·880, when pure and genuine. Now I found that 2000 grain-measures of oil of turpentine ran off through the small siphon in 95 seconds, while that quantity of sperm oil took 2700 seconds, being in the ratio of 1 to $28\frac{1}{4}$; so that the fluency of oil of turpentine is $28\frac{1}{4}$ times greater than that of sperm oil. Pyroxilic spirit, commonly called naphtha, and alcohol, each of specific gravity 0·825, were found to run off respectively in 80 and 120 seconds; showing that the former was 50 per cent. more fluent than the latter. Sperm oil, when heated to 265° Fahr., runs off in 300 seconds, or one-ninth of the time it took when at the temperature of 64°. Southern whale oil, having a greater density than the sperm oil, would flow off faster were it not more viscid.

2000 grain measures of water at 60° run off through the said siphon in 75 seconds, but when heated to 180° they run off in 61.

Concentrated sulphuric acid, though possessing the great density of 1·840, yet flows off very slowly at 64°, on account of its viscidity; whence its name of oil of vitriol. 2000 grain-measures of it took 660 seconds to discharge.

LAMPIC ACID. *Syn.* Aldehydic acid; Acetylous acid. (*Acide Lampique*, Fr.) If a little ether be placed at the bottom of a glass, and some spongy platinum attached to a wire of the same metal be ignited and suspended about an inch from the fluid, it will glow and continue to do so for a long time. On the other hand, if a spiral of platinum wire be placed over the wick of a spirit lamp, and the latter be first ignited and then blown out, the wire will continue at a red heat until all the spirit is exhausted. Numerous sesquioxides, when placed warm on wire gauze over capsules containing

alcohol, will glow in the same manner. Under all these circumstances, a powerful odour resembling aldehyde is evolved, which strongly affects the eyes. If this experiment be made in such a manner that the volatile product may be condensed, it will be found to be strongly acid. It is powerfully reducing in its tendency, and if heated with the oxides of silver or gold, converts them into the metallic state, and the liquid is found to contain acetic acid and resin of aldehyde. If, however, the acid liquid be only very gently warmed with oxide of silver, a portion of the latter is dissolved; but when baryta is added to precipitate the silver as oxide, and the fluid is warmed, the metal instead of the oxide comes down, and the fluid when tested for the nature of the acid, is found to contain nothing but acetate of baryta. These phenomena are explained by some chemists by supposing the fluid to contain an acid which they, following the late Professor Daniell, call the lampic, and supposed to contain $C^4H^4O^3$. When lampic acid is treated first with oxide of silver and then with baryta water and heated, they consider that the oxygen of the oxide of silver is transferred to the lampic acid, converting it into acetic acid, which combines with the baryta, while the metallic silver is precipitated. The following equation explains the reaction supposed to take place: —

$$\underbrace{C^4H^4O^3}_{\text{Lampic acid.}} + BaO + AgO = \underbrace{C^4H^3O^3,BaO}_{\text{Acetate of baryta.}} + Ag + HO.$$

The conversion of the lampic into acetic acid is therefore attributed to the oxidising tendency of the oxide of silver. Those who regard the decomposition from the above point of view, consider lampic acid to be acetylous acid, that is to say, to bear the same relation to acetylic acid (acetic acid) that sulphurous acid does to sulphuric acid.

The above explanation, although simple, does not really render a satisfactory account of the reactions which bear upon the subject. Aldehyde, when treated with oxide of silver does, it is true, become converted into the same, or apparently the same, substance as lampic acid, but the probabilities are in favour of Gerhardt's supposition, that the lampates are in fact aldehyde, in which an equivalent of hydrogen is replaced by a metal. That the aldehydes are capable of uniting with metals with elimination of hydrogen has been, on more than one occasion, proved by experiment. There is great difficulty in preparing the sodium aldehyde of the vinic series, but the author of this article has found that if cenodic aldehyde from oil of rue be treated with sodium, a definite compound is formed, having the formula $\left.\begin{matrix} C^{22}H^{21}O^2 \\ Na \end{matrix}\right\}$.

If, therefore, we admit aldehyde to be formed on the hydrogen type, that is to say, two atoms of hydrogen in which one is replaced by the oxidised radical acetyl, we shall have for aldehyde: — $\left.\begin{matrix} C^4H^3O^2 \\ H \end{matrix}\right\}$; and for the lampates, acetylurets, or aldehydates: — $\left.\begin{matrix} C^4H^3O^2 \\ M \end{matrix}\right\}$. M. Gerhardt, who views the lampates in the above light, regards aldehyde as the true acetylous acid. See ACETYL. — C. G. W.

LANCE WOOD. *Uvaria lanceolata* or *Guatteria virgata*. This wood is imported from Jamaica and Cuba in long poles from 3 to 6 inches diameter. Lance wood is paler in colour than box; it is selected for elastic works, as gig-shafts, archery bows, springs, &c. These are bent into the required form by boiling or steaming. Surveyor's rods, ordinary rules and billiard cues are made of lance wood.

LANDER. In mining, the man who attends at the mouth of the shaft to receive the "hibble of ore" as it reaches the surface.

LAPIDARY, *Art of*. The art of the lapidary, or that of cutting, polishing, and engraving gems, was known to the ancients, many of whom have left admirable specimens of their skill. The Greeks were passionate lovers of rings and engraved stones; and the most parsimonious among the higher classes of the Cyrenians are said to have worn rings of the value of ten minæ (about 30*l.* of our money). By far the greater part of the antique gems that have reached modern times, may be considered as so many models for forming the taste of the student of the fine arts, and for inspiring his mind with correct ideas of what is truly beautiful. With the cutting of the diamond, however, the ancients were unacquainted, and hence they wore it in its natural state. Even in the middle ages, this art was still unknown; for the four large diamonds which enrich the clasp of the imperial mantle of Charlemagne, as now preserved in Paris, are uncut, octahedral crystals. But the art of working diamonds was probably known in Hindostan and China in very remote periods. After Louis de Berghen's discovery, in 1476, of polishing two diamonds by their mutual attrition, all the finest diamonds were sent to Holland to be cut and polished by the Dutch artists, who long retained a superiority, now no longer admitted by the lapidaries of London and Paris. See DIAMOND.

The operation of gem cutting is abridged by two methods; 1, by cleavage; 2, by cutting off slices with a fine wire, coated with diamond powder, and fixed in the stock of a hand-saw. Diamond is the only precious stone which is cut and polished with diamond powder, soaked with olive oil upon a mill plate of very soft steel.

Oriental rubies, sapphires, and topazes, are cut with diamond powder soaked with olive oil, on a copper wheel. The facets thus formed are afterwards polished on another copper wheel, with tripoli, tempered with water.

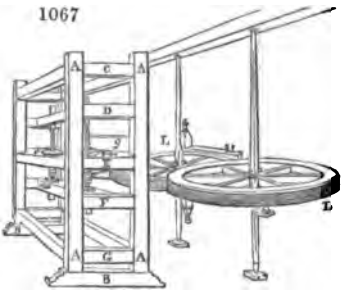
Emeralds, hyacinths, amethysts, garnets, agates, and other softer stones, are cut at a lead wheel, with emery and water; and are polished on a tin wheel with tripoli and water, or, still better, on a zinc wheel, with putty of tin and water.

The more tender precious stones, and even the pastes, are cut on a mill-wheel of hard wood, with emery and water; and are polished with tripoli and water on another wheel of hard wood.

Since the lapidary employs always the same tools, whatever be the stone which he cuts or polishes, and since the wheel discs alone vary, as also the substance he uses with them, we shall describe, first of all, his apparatus, and then the manipulations for diamond cutting, which are applicable to every species of stone.

The lapidary's mill, or wheel, is shown in perspective in *fig.* 1067. It consists of a strong frame made of oak carpentry, with tenon and mortised joints, bound together with strong bolts and screw nuts. Its form is a parallelopiped of from 8 to 9 feet long, by from 6 to 7 high; and about 2 feet broad. These dimensions are large enough to contain two cutting wheels alongside of each other, as represented in the figure.

1067

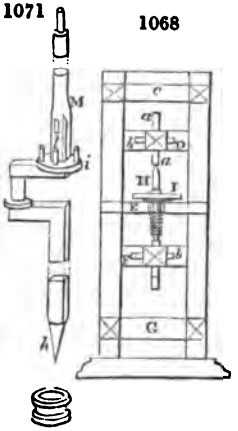


Besides the two sole bars B B, we perceive in the breadth, 5 cross bars, C, D, E, F, G. The two extreme bars C and G, are a part of the frame-work, and serve to bind it. The two cross-bars D and F, carry each in the middle of their length, a piece of wood as thick as themselves, but only 4½ inches long (see *fig.* 1067), joined solidly by mortises and tenons with that cross bar as well as with the one placed opposite on the other parallel face. These two pieces are called *summers* (lintels); the one placed at D is the upper; the one at F the lower.

In *fig.* 1068 this face is shown inside, in order to explain how the mill wheel is placed and supported. The same letters point out the same objects, both in the preceding and the following figures.

In each of these *summers* a square hole is cut out, exactly opposite to the other in which are adjusted by friction a square piece of oak, *a a*, *fig.* 1068, whose extremities are perforated with a conical hole, which receives the two ends of the arbor H of the wheel I, and forms its socket. This square bar is adjusted at a convenient height by a double wooden wedge, *b b*. The cross bar in the middle E, supports the table *c c*, a strong plank of oak. It is pierced with two large holes, whose centres coincide with the centres of the conical holes hollowed out at the end of the square pins. These holes of about 6 inches diameter each, are intended to let the arbor pass freely through, bearing its respective wheel. (See one of these holes at I, in *fig.* 1072 below.)

1071 1068



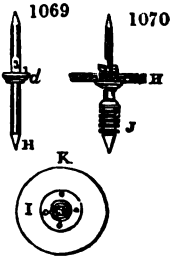
Each wheel is composed of an iron arbor H, *fig.* 1068, of a grinding wheel I, which differs in substance according to circumstances, as already stated, and of the pulley J, furnished with several grooves (see *fig.* 1070), which has a square fit upon the arbor. The arbor carries a collet *d*, on which are 4 iron pegs or pins that enter into the wheel to fasten it.

The wheel plate, of which the ground plan is shown at K, is hollowed out towards its centre to half its thickness; when it is in its position on the arbor, as indicated in *fig.* 1069, a washer or ferrule of wrought iron is put over it, and secured in its place by a double wedge. In *fig.* 1069 the wheel-plate is represented in section, that the connection of the whole parts may be seen.

A board *g* (see *fig.* 1067 and *fig.* 1075), about 7½ inches high, is fixed to the

part of the frame opposite to the side at which the lapidary works, and it prevents the substances made use of in the cutting and polishing from being thrown to a distance by the centrifugal force of the wheel-plate.

1069 1070

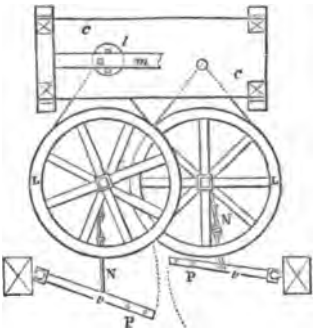


Behind this apparatus is mounted for each grinding-plate, a large wheel L (see *fig.* 1067), similar to a cutler's, but placed horizontally. This wheel is grooved round its circumference to receive an endless cord or band, which passes round one of the grooves of the pulley J, fixed below the wheel-plate. Hence, on turning the fly-wheel L, the plate revolves with a velocity relative to the velocity communicated to the wheel L, and to the difference of diameter of the wheel L and the pulley J. Each wheel L, is mounted on an iron arbor, with a crank (see M, *fig.* 1071).

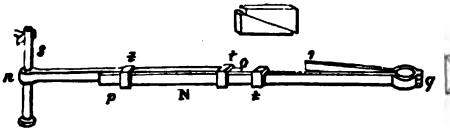
The lower pivot of that arbor *h* is conical, and turns in a socket fixed in the floor. The great wheel L rests on the collet *i*, furnished with its 4 iron pins, for securing the connection. Above the wheel an iron washer is laid, and the whole is fixed by a double wedge, which enters into the mortise *l*, *fig.* 1071.

Fig. 1072 exhibits a ground-plan view of all this assemblage of parts, to explain the structure of the machine. Everything that stands above the upper *summer-bar* has been suppressed in this representation. Here we see the table *c c*; the upper *summer m*; the one wheel-plate *l*, the other having been removed to show that the endless cord does not cross; the two large wheels L L, present in each machine, the crank bar N, seen separate in *fig.* 1073, which serves for turning the wheel L.

1072



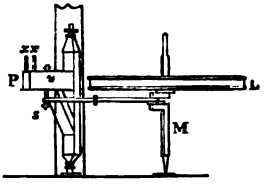
1073



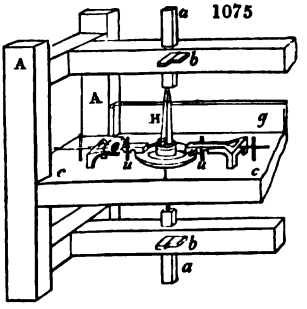
This bar is formed of 3 iron plates *n*, *o*; *p*, *q*; and *q*, *r* (*fig.* 1073). The first is bent round at the point *n*, to embrace the stud *s*; the second *p q*, is of the same breadth and thickness as the first; and the third, is adjusted to the latter with a hinge joint, at the point *q*, where they are both turned into a circular form, to embrace the crank M. When all these pieces are connected, they are fixed at the proper lengths by the buckles or square rings *t t t*, which embrace these pieces, as is shown in *fig.* 1072.

The stud *s*, seen in *fig.* 1073, is fixed to the point *v*, by a wedge-key upon the arm P, represented separately, and in perspective, in *fig.* 1074. The labourer seizing

1074



1075



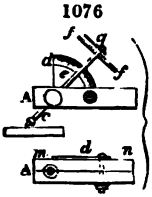
the two upright pegs or handles *x x*; by the alternate forward and backward motion of his arm, he communicates the same motion to the crank rod, which transmits it to the crank of the arbor M, and impresses on that arbor, and the wheel which it bears, a rotatory movement.

Fig. 1075 shows piece-meal and in perspective a part of the lapidary's wheel-mill. There we see the table *c c*, the grind plate I, whose axis is kept in a vertical position by the two square plugs *a a*, fixed into the two *summers* by the wedges *b b*. On the two sides of the wheel-plate, we perceive an important instrument called a *dial*, which

serves to hold the stone during the cutting and polishing. This instrument has received lately important ameliorations, to be described in *fig.* 1076. The lapidary holds this instrument in his hand, he rests it upon the iron pins *u u*, fixed in the table, lest he should be affected by the velocity of the revolving wheel-plate. He loads it sometimes with weights *e e*, to make it take better hold of the grinding plate.

Fig. 1076, shows an improvement made by one of the most expert lapidaries of Geneva, whereby he cuts and polishes the facet with extreme regularity, converting it into a true dial. Each of the two jaws bears a large conchoidal cavity, into which is fitted a brass ball, which carries on its upper part a tube *e*, to whose extremity is fixed a dial-plate *f f*, engraved with several concentric circles, divided into equal parts, like the toothed-wheel cutting engine-plate, according to the number of facets to be placed in each cutting range. The tube receives with moderate friction the handle of the cement rod, which is fixed at the proper point by a thumb-screw, not shown in the figure, being concealed by the vertical limb *d*, about to be described.

1076



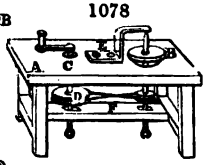
A needle or index *g*, placed with a square fit on the tail of the cement rod, marks by its point the divisions on the dial plate *f f*. on the side *m n*, of the jaw A, there is fixed by two screws, a limb *d*, forming a quadrant whose centre is supposed to be at the centre of the ball. This quadrant is divided as usual into 90 degrees, whose highest point is marked 0, and the lowest would mark about 70; for the remainder of the arc down to 90 is concealed by the jaw. The two graduated plates are used as follows:—

When the cement rod conceals zero or 0 of the limb, it is then vertical, and serves to cut the table of the brilliant; or the point opposite to it, and parallel to the table. On making it slope a little, 5 degrees for example, all the facets will now lie in the same zone provided that the inclination be not allowed to vary. On turning round the cement rod the index *g* marks the divisions so that by operating on the circle with 16 divisions, stopping for some time at each, 16 facets will have been formed, of perfect equality, and at equal distances, as soon as the revolution is completed.

In cutting the stones, they are mounted on the cement-rod B, *fig.* 1077, whose stem is set upright in a socket placed in a middle of a sole piece at A, which receives the stem of the cement-rod. The head of the rod fills the cup of A. A melted alloy of tin and lead is poured into the head of the cement-rod, into the middle of which the stone is immediately plunged; and wherever the solder has become solid, a portion of it is pared off from the top of the diamond, to give the pyramidal form shown in the figure at B.

1077

1078



There is an instrument employed by the steel polishers for pieces of clock work, and by the manufacturers of watch-glasses for polishing their edges. It consists of a solid oaken table *fig.* 1078. The top is perforated with two holes, one for passing through the pulley and the arbor of the wheel plate B made either of lead or of hard wood, according to circumstances; and the other C for receiving the upper part of the arbor of the large pulley D. The upper pulley of the wheel plate is supported by an iron prop E, fixed to the table by two wooden screws. The inferior pivots of the two pieces are supported by screw sockets, working in an iron screw nut sunk into the summer bar F. The legs of the table are made longer or shorter, according as the workman chooses to stand or sit at his employment. Emery with oil is used for grinding down, and tin putty or colcothar for polishing. The workman lays the piece on the flat of the wheel plate with one hand, and presses it down with a lump of cork, while he turns round the handle with the other hand. See the different GEMS under their respective heads.

LAPIS LAZULI. A silicate of soda, lime, and alumina, with the sulphide of iron and sodium in minute quantities. This beautiful mineral is found in crystalline limestone of a greyish colour, on the banks of the Indus, and in granite in Persia, China, and Siberia.

The finest varieties are highly esteemed, being employed in the manufacture of costly vases. It was also the source from which the beautiful pigment ultramarine, was obtained, but this colour is now prepared artificially at a very cheap rate. See ULTRAMARINE.

LAPS. Metal polishing wheels. Metal wheels or laps made of nearly every metal and alloy in common use, have been more or less employed in the mechanical arts as vehicles for the application of several of the polishing powders. But of all laps, notwithstanding their variety, those of lead, slightly alloyed, and supplied with powdered emery, render the most conspicuous service. Generally the plane, or flat surface

of the lap, is employed; at other times the cylindrical edge, as by cutlers; but the portion actually used in either case called the *face* of the lap. There are several kinds of laps. The lap is in some cases a thin disc of metal, fixed by means of a screwed nut against a shoulder on the spindle, but it is better with lead laps to employ an iron plate cast full of holes, to support the softer metal. The casting mould may in this case be either an iron disc, with a central screw to fix the iron centre plate at the time of pouring, or the mould may be made of sand and in halves, after the usual manner of the foundry. In either case the iron plate should be made as hot as the fluid metal, which, by entering the holes, becomes firmly united to the iron, especially if the holes are largest on the reverse side, or that away from the lead.—*Holtzapffel.*

Lap is also a roll or sliver of cotton for feeding the cards of a spinning machine.

LARD. The fat of the pig. Our imports from the United States have been in 1857:—

	Cwts.	Computed real value.
In British vessels - -	39,207	
In Foreign vessels - -	129,188	
	168,295	£561,684

LARD OIL. Lard being subjected to pressure, an oil, *oleine*, is expressed, *stearine* being left. This lard oil is much used for lubricating machinery, and it was employed for the adulteration of olive oil.

LASKS. All Indian cut stones are called *lasks*. They are in general ill shaped or irregular in their form, their depth ill proportioned. The table, or face, seldom in the centre of the stone, sometimes too broad or too small, and none properly polished. The chief thing regarded is saving the size and weight of the stone. These stones are always new wrought when brought to Europe.

LATH WOOD. The outside cuttings of fir trees, used for being split into laths.

LATTEN is a somewhat antiquated term, which was applied to several kinds of sheet metal. "Mines of *latten*, whatever may have been meant by the word are mentioned in the time of Henry VI., who made his chaplain, John Botteright, comptroller of all his mines of gold, silver, copper, latten, lead, within the counties of Devon and Cornwall." Is tin meant by the term?—*Watson's Chemical Essays.*

In the reigns of Henry VIII. and Edward VI., several acts of parliament were passed, prohibiting the exportation of brass, copper, *latten*, bell metal, gun metal, schrof metal, &c. Windows framed with lead are called *lattice* windows in the West of England.

The term is now applied to sheet or plate brass. *Black latten* is rolled sheets; *shaven latten* is in *thinner sheets*, and *roll latten* is polished on both sides.

LAUNDER. A miner's term for a wooden tube or gutter to convey water. A long shallow trough carrying off the ore from the stamps.

LAVA. The ejected matter of volcanoes. "The stone which flows in a melted state from a volcano." (*Lyell.*) M. Abich obtained from the lava of 1669, 48·83 silica. He made the lava to consist of 54·80 labradorite, 34·16 augite, 7·98 olivine, and 3·08 magnetic iron.

Bischoff gives the following two analyses of lava:—

	Hecla.	Etna.
Silica - - - - - -	54·76	49·63
Alumina - - - - -	13·61	22·47
Peroxide of iron - - - -	15·60	10·80
Lime - - - - - -	6·14	9·05
Magnesia - - - - -	1·35	2·68
Potash - - - - - -	3·41	3·07
Soda - - - - - -	1·21	0·98

LAVA WARE. A peculiar stoneware, manufactured and coloured to assume the semi-vitreous appearance of lava.

LAVER. *Porphyra laciniata* and *Ulva latissima*. (See ALGÆ.)

LAVENDER, oil of. See PERFUMERY.

From the flowers of the *Lavandula spicata* the oil of spike is obtained, which is used by painters on porcelain, and by artists in the preparation of some varnishes.

LAWN. A fine linen fabric.

LAZULITE (Eng. and Fr.; *Lazulith*, Germ.), from an Arabic word, *azul*, meaning *heaven*. It is a blue vitreous mineral, found massive and crystalline, traversing clay slate, and sometimes united with spathic iron; spec. grav. 2·76 to 2·94; scratches glass; affords a little water by calcination; fusible into a white glass; dissolves in

acids with loss of colour; the solution leaves an alkaline residuum, after being treated with carbonate of ammonia, filtered, evaporated, and calcined. By analysis it is found to consist of: —

	1.	2.
Phosphoric acid	43·88	46·79
Alumina	31·77	27·10
Protoxide of iron	8·90	7·10
Magnesia	9·89	11·87
Water	5·56	7·12

LEAD. (*Plomb*, Fr.; *Blei*, Germ.) This metal appears to have been known at a very early period. It is mentioned by Moses, as a metal in common use. Job describes mining for lead, and the metallurgic processes of refining and separating silver from lead are very clearly described by both Job and Jeremiah. Lead has a bluish-grey colour, and, when recently cut, it exhibits considerable lustre, which, however, it speedily loses. It is one of the softest of the ordinary metals, is easily cut with a knife, may be scratched with the nail, and marks paper with a grey stain. Lead is malleable, and may be beaten into thin leaves, but these are of very imperfect tenacity; hence, it cannot be drawn into thin wire; a wire of $\frac{1}{12}$ of an inch in diameter will not support 20 lbs.

If lead be prepared in a very finely divided state, it is *pyrophoric*. This is usually prepared from the tartrate of lead, by heating it in a glass tube as long as any fumes are evolved, consequently it is finely divided lead combined with some carbon. As soon as the fumes cease the tube must be closed at the blowpipe-lamp. If at any time the tube is broken, and the powder scattered in the air, it burns with a red flash.

If lead is heated in closed vessels, it fuses at 635° F. (335° Cent.), and at a red heat, it gives off vapours. If fused lead is allowed to cool slowly, it crystallises in a somewhat peculiar manner, the crystals are referrible to the octahedral system, but they group themselves in a very complicated and interesting way. By the electro-chemical action of zinc on a solution of the acetate of lead, crystals of that metal are obtained in an arborescent form. This experiment is usually spoken of as the formation of *Saturn's tree*, Saturn being the alchemic name for this metal.

When fused in the air, lead oxidises rapidly, and it becomes covered with an iridescent pellicle, often of great beauty. It then passes into a yellow powder (Litharge), protoxide of lead.

Pure lead is not affected by perfectly pure water free from air, but if air be present the metal is oxidised at its expense, and the oxide thus formed, combining with carbonic acid, is deposited on the lead in minute crystals as a basic carbonate of lead. The water will then be found to contain lead in solution, and such waters drawn from impure cisterns often produce very distressing consequences. If the water contains any sulphates, the lead is thrown down as a sulphate of lead, which is insoluble.

The native formations are the following. The localities, &c., are mainly derived from Greg and Lettsom's *Manual of the Mineralogy of Great Britain and Ireland*.

1. *Native lead.* Mr. Greg appears to doubt the existence of native lead in this country. He says, however, "Native lead has been recently discovered in undoubtedly genuine specimens in the province of Guanaxuato in Mexico." Some equally genuine specimens of native lead have been found in the Grassington mines; these are in the possession of the Duke of Devonshire and of Stephen Eddy, Esq.

2. *Minium. Native oxide of lead.* This ore is found in Anglesea, at Alston Moor, the Snailbeach Mine in Shropshire, at Grassington, the Leadhills in Scotland, and Wicklow in Ireland. Its composition is—lead, 90·66, oxygen, 9·34.

3. *Cerussite. Carbonate of lead.* This ore occurs in crystals, in fibrous, compact, and earthy masses. It is found at several of the lead mines of Cornwall and Devonshire, and indeed in nearly all the mines producing the ores of lead, varying much in its character with the different conditions under which it has been formed.

This ore, in its purest state, is colourless and transparent like glass, with an adamantine lustre. It may be recognised by the following characters:

Its specific gravity is from 6 to 6·7; it dissolves with more or less ease, and with effervescence, in nitric acid; becomes immediately black by the action of sulphuretted hydrogen, and melts on charcoal before the blowpipe into a button of lead. According to Klaproth, the carbonate of Leadhills contains 82 parts of oxide of lead, and 16 of carbonic acid, in 98 parts. This mineral is tender, scarcely scratches calc-spar, and breaks easily with a waved conchoidal fracture. It possesses the double refracting property in a very high degree; the double image being very visible on looking through the flat faces of the prismatic crystals. Its crystalline forms are very numerous, and are referrible to the rhombohedron.

4. *Anglesite. Sulphate of lead*, or *Vitreous lead.*—This mineral closely resembles car-

bonate of lead; so that the external characters are inadequate to distinguish the two. But the following are sufficient. When pure, it has the same transparency and lustre. It does not effervesce with nitric acid; it is but feebly blackened by sulphuretted hydrogen; it first decrepitates and then melts before the blowpipe into a transparent glass, which becomes milky as it cools. By the combined action of heat and charcoal, it passes first into a red pulverulent oxide, and then into metallic lead. It consists, according to Klaproth, of 71 oxide of lead, 25 sulphuric acid, 2 water, and 1 iron. The specimen was from Anglesea; the Wanlockhead mineral is free from iron. The prevailing form of crystallisation is the rectangular octahedron, whose angles and edges are variously modified. This mineral was first recognised in Anglesea, hence its name. It was found in the Channel Islands at Sark mine, and is occasionally met with in the Leadhills and Wanlockhead in Scotland, at Glemalure in Wicklow, and at Ballycorns mine, Co. Dublin.

Leadhillite. Sulphato-tricarbonate of lead.—This ore is of a yellowish white colour, inclining to grey, sometimes yellowish-green, yellow and brown. Its chemical composition is—

Sulphate of lead	28·7
Carbonate of lead	71·0
	99·7

5. *Pyromorphite. Phosphate of lead.*—This, like all the combinations of lead with an acid, exhibits no metallic lustre, but a variety of colours. Before the blowpipe, upon charcoal, it melts into a globule externally crystalline, which by a continuance of the heat, with the addition of iron and boracic acid, affords metallic lead. Its constituents are 80 oxide of lead, 18 phosphoric acid, and 1·6 hydrochloric acid, according to Klaproth's analysis of the mineral from Wanlockhead. The constant presence of chlorine in the various specimens examined is a very remarkable circumstance. The crystalline forms are derived from an obtuse rhomboid. Phosphate of lead is a little harder than white lead; it is easily scratched, and its powder is always grey. Its specific gravity is 6·9. It has a vitreous lustre, somewhat adamantine. Its lamellar texture is not very distinct; its fracture is wavy, and it is easily frangible. The phosphoric and arsenic acids being, according to M. Mitscherlich, isomorphous bodies, may replace each other in chemical combinations in every proportion, so that the phosphate of lead may include any proportion, from the smallest fraction, of arsenic acid, to the smallest fraction of phosphoric acid, thus graduating indefinitely into arseniate of lead. The yellowish variety indicates, for the most part, the presence of arsenic acid. It is found in Cornwall, Devonshire, Yorkshire, and Derbyshire.

6. *Mimetite. Arseniate of lead.*—The name is derived from *μιμητης, imitator*, the species so nearly resembling pyromorphite. The colour of this ore varies from straw yellow and wax yellow to brown, reddish-brown, orange, yellow, and red. Before the blowpipe, on charcoal, it emits arsenical fumes and yields a bead of lead. The analysis by Dufrenoy gives the following as its composition:—

Arseniate of lead	84·55
Phosphate of lead	4·50
Chloride of lead	9·05

At Drygill, in Cumberland, this ore has been met with in sufficient abundance to be worked to some extent as an ore of lead. The mimetite from this mine was used in the manufacture of flint glass, to which it gave great brilliancy. The form of the arseniate of lead, when it is crystallised, is a prism with six faces, of nearly the same dimensions as that of phosphate of lead. When pure, it is reducible upon charcoal, before the blowpipe, into metallic lead, with the copious exhalation of arsenical fumes; but only in part, and leaving a crystalline globule, when it contains any phosphate of lead. The arseniate of lead is tender, friable, sometimes even pulverulent, and of specific gravity 5·04. That of Johann-Georgenstadt consists, according to Rose, of oxide of lead, 77·5; arsenic acid, 12·5; phosphoric acid, 7·5; and chlorine, 1·5.

7. *Galena. Sulphide of lead.*—This is the most abundant ore of lead; it may be indeed regarded as the only commercial ore of any value, if we except the carbonates, which are probably formed by the decomposition of galena. Its prevailing forms are the cube and a combination of the cube and octahedron; lustre metallic, opaque, colour and streak *lead grey*. Fracture conchoidal, but difficult to obtain, owing to the readiness with which it cleaves. The localities of galena need not be named here, as the lead producing districts, of which a list will be presently given, will include them, and galena is included in them all. Thomson's analysis of galena gives—

Lead	85·13
Iron	0·50
Sulphur	13·02

8. *Jamesonite* is a combination of lead and antimony. It occurs in acicular crystals, or in parallel or diverging groups, and more frequently in fibrous masses. It is found in many places in Cornwall and Devon. Rose's analysis gives the following as its composition:—

Lead	38·71
Iron	2·96
Copper	0·21
Zinc	0·74
Antimony	34·90
Sulphur	25·53
	103·05

This mineral may be regarded as a double sulphide of lead and antimony, analogous to the double sulphide of copper and iron.

9. *Cromfordite. Chloride of lead. Horn-lead*, or *chloro-carbonate.*—This ore has a pale yellow colour, is reducible to metallic lead by the agency of soda, and is not altered by the hydrosulphides. Before the blowpipe it melts first into a pale yellow transparent globule, with salt of phosphorus and oxide of copper, and manifests the presence of chlorine. It is fragile, tender, softer than carbonate of lead, and is sometimes almost colourless, with an adamantine lustre. Spec. grav. 6·06. Its constituents, according to Berzelius, are, lead, 25·84; oxide of lead, 57·07; carbonate of lead, 6·25; chlorine, 8·84; silica, 1·46; water, 0·54, in 100 parts.

10. *Plattnerite. Superoxide of lead.*

11. *Linarite. Cupreous sulphate of lead.*

12. *Susannite. Sulphato-tricarbonate of lead.*

13. *Lanarkite. Sulphato-carbonate of lead.*

14. *Calcedonite. Cupreous sulphato-carbonate of lead.*

15. *Vanadinite. Vanadiate of lead.*

16. *Wulfenite. Tungstate of lead.*

17. *Stolzite. Molybdate of lead.*

18. *Geocronite. Sulphide of lead and antimony*

19. *Mendipite*, an *Oxychloride of lead.*

20. *Matlockite*, *ditto.*

21. *Red lead*, or *Chromate of lead.*—This mineral is too rare to require consideration in the present work.

22. *Plomb Vauquelinite. Chromate of lead and copper.*

The ores of lead, which may be represented by galena, or the sulphide of lead, that being the truly commercial variety, are found in rocks of different ages from the granite and clay slates to the triasic formations. In the Devonian slate rocks, in the neighbourhood of Liskeard in Cornwall are many most productive lead mines. To the north of Truro is the lead mine Huel Rose, which has from its long celebrity given its name to the district; and again to the south of Helstone there have been some valuable workings for lead. These formations of lead ore have all been in the clay slate, "killas" rocks of Cornwall. In Devonshire many most valuable lead mines have been worked in similar rocks. In these the celebrated mines of Beer Alston on the Tamar exist. With a very few exceptions but little lead has been discovered in the black slates,—the carboniferous series of Devonshire. Some lead ore has, however, been discovered in the new red sandstone and in the slate rocks immediately adjoining them near Newton St. Cyres. To the north of the carboniferous rocks of Devonshire we have a renewal of clay slate rocks, similar in all respects to those which are found near Liskeard in Cornwall; in these rocks are the once famous argentiferous lead mines of Combe Martin, from which Edward the Black Prince derived an immense revenue.

The lead mines of the Mendip Hills which were at one time very productive, but which are now producing but small quantities of lead ore, are in the mountain limestone formations. Those of Cardiganshire are found in clay-slates and gritstones, correspondent with or underlying the lowest beds described by Sir R. Murchison in his Silurian System.— *Smyth.*

In Shropshire we have lead ore occurring in the original silurian rocks, the Llandeilo formation. "In that lofty and rugged district of Shropshire which lies around the village of Shelve and the Corndon mountains, and which extends west of the Stiper Stones range into Montgomeryshire" (*Murchison*), lead lodes are abundant. In Derbyshire, in Yorkshire, in Cumberland, Northumberland, and Durham, the lead mines prove the most productive in the mountain limestone formations, although there are some instances in which good lead mines have been worked in the sandstones and shales. In addition to these, we have the mines in the Leadhills and at Wanlock-

head, consisting chiefly of the graywacke slates, in Scotland. Luganure, &c. in the granite districts of Wicklow, Newtonards in County Down, with a few others in Ireland, and the lead mines in the Silurian rocks of the Isle of Man. These are the principal districts from which our large supplies of lead ore are obtained.

The extensive lead mines of Mr. Beaumont, which have for many years produced about one-fourth of the quantity raised in England, about one-sixth of the produce of Great Britain, and about one-tenth of that of the whole of Europe, including the British Isles, are so important, and in many respects so characteristic, that much of the description of them which appeared in the former edition is retained, as representing many of the peculiar and important features of lead mining. An extensive section of this great lead mining district is in the Mining Record Office of the Museum of Practical Geology. This section was executed by Mr. Sopwith, and together with a series of models explains nearly all the phenomena of mineral veins.

The datum or base line of the Allenheads section is 700 feet above the level of the sea. The drawing, 16¼ feet in length, is on a true scale of 100 feet to an inch; by a true scale being meant, that the lengths and heights are projected to the scale or proportion, so that a true miniature profile of the country is given, as well as a correct reduction of the relative size of the various rocks. The extent of country thus shown is not quite 4 miles, being 3 miles 1,220 yards.

The spectator is supposed to be looking to the north, and the section commences at a point about half a mile eastward from a place called Kilhope Head, which is conspicuously marked in all English maps, inasmuch as the three counties of Northumberland, Durham, and Cumberland here meet in one spot. At about three quarters of a mile from the point of commencement, the section represents the hill called Kilhope Law; it is on the boundary line of the counties of Northumberland and Durham, and is the highest point of land in the last-named county, being 2206 feet above the level of the sea. But out of the limits of this section, and about 10 miles south-west from Kilhope Law, the same strata which are here delineated reach an altitude of 2901 feet above the sea, and this is the highest elevation attained by the rocks which form the carboniferous or mountain limestone of the north of England.

Such being the stratification of the central portion of the narrow part of the island, of which the coal fields of the Tyne and Wear form the extremity on the east bordering the German Ocean, for some distance north and south of Newcastle, while a similar coal field is found at the western extremity near Whitehaven, it may be observed with reference to these coal fields, that they lie over or upon the mountain limestone formation. The coal beds so extensively worked in the Newcastle and Durham coal mines or collieries gradually rise to the west, and one by one crop out or basset according to the undulations of the country. At length at about 20 miles west of the German Sea, the lowest of the coal beds crops out, and from beneath it gradually appear the limestone strata, which continue to rise nearly coincident with the general rise of the country, until they reach the summit of Cross Fell (2901 feet). This general and very gradual inclination of the strata, a feature of the greatest importance in practical mining, is clearly and accurately delineated in this section.

In a thickness of about 2000 feet of the alternating beds of sandstone, clay, and limestone which form the strata of the mining districts of Allendale, Alston, and Weardale, there is one single stratum of limestone, called the "great limestone," the veins in which have produced nearly, if not quite, as much ore as all the other strata put together. This stratum, delineated on the section, lies at a depth of about 850 feet below the summit of Kilhope Law. Somewhat exceeding 2 miles eastward of this, at Allenheads, the top of the great limestone is 230 feet from the top of a shaft called Gin-Hill Shaft. Its thickness, which is tolerably uniform over several hundred square miles of country, is about 60 feet; and it is in this stratum of limestone that the largest quantity of lead has been found.

The dislocations of strata which constitute for the most part important mineral veins, are exhibited more in detail in the series of geological models already referred to.

At about a quarter of a mile to the west of, or left hand direction from Kilhope Law, the great limestone, and all other associated beds are thrown down a depth of about 150 feet for a space of nearly 700 feet; and again, at the distance of nearly a mile from Allenheads, a vast dislocation takes place, by which the great limestone is brought nearly to the surface, the amount of displacement being about 400 feet. It is in the great limestone that by far the most extensive portion of the workings of Allenheads lead mines are situated, and the galleries or levels are very extensive. In a great thickness of strata above the great limestone, only two beds of that rock are found. One of these is called "little limestone." It is from 10 to 12 feet thick, and is 75 feet above the top of the great limestone. The other is still more inconsiderable, being only 3 or 4 feet thick, and is 440 feet above the great

limestone. It is remarkable with what exactness this thin bed is found near the summit of hills, the intervening spaces having apparently been removed by denudation, so as to form in one case a gap of 6¼ miles, and in another of 1¼ miles, in which the Tell Top limestone is entirely cut off.

But beneath the great limetone, are several beds of the same description of rock, viz. at distances respectively of 30, 106, 190, 250, and 287 feet, and the thickness 2, 24, 10, 15, and 35 feet. These are known by descriptive local names, and comprise all that are of significance as regards lead mining operations.

The Allenheads mines being situated for the most part at depths from the surface varying from 200 to 600 feet are drained, partly by ordinary waterwheels, and partly by hydraulic engines constructed by Mr., now Sir W. G. Armstrong. See WATER PRESSURE ENGINES.

Such is a general view of the lead mining districts of England. The following brief account of foreign lead mines is retained from the last edition. Much additional information will be found in the article MINES.

The principal lead mines at present worked in other parts of the world are the following :— 1. Poullaouen and Huelgöet, near Carhair in France, department Finisterre, being veins of galena, which traverse a clay slate resting on granite. They have been known for upwards of three centuries ; the workings penetrate to a depth of upwards of 300 yards, and in 1816, furnished 500 tons of lead per annum, out of which 1034 pounds avoidupois of silver were extracted. 2. At Villefort and Viallay, department of Lozère, are galena mines said to produce 100 tons of lead per annum, 400 kilogrammes of silver (880 lbs. avoird.). 3. At Pezey and Macot, to the east of Moutiers in Savoy, a galena mine exists in talc-schist, which has produced annually 200 tons of lead, and about 600 kilogrammes of silver (1230 lbs. avoird.). 4. The mine of Vedrin near Namur in the Low Countries, is opened upon a vein of galena, traversing compact limestone of a transition district; it has furnished 200 tons of lead, from which 385 pounds avoirdupois of silver were extracted. 5. In Saxony the galena mines are so rich in silver as to make the lead almost overlooked. They are enumerated under silver ores. 6. The lead mines of the Harz have been likewise considered as silver ones. 7. Those of Bleyberg in the Eifel, are in the same predicament. 8. The galena mines of Bleyberg and Villach in Carinthia, in compact limestone. 9. In Bohemia to the south-west of Prague. 10. Mines of Joachimsthal and Bleistadt on the southern slope of the Erzgebirge, produce argentiferous galena. 11. There are numerous lead mines in Spain, the most important being in the granite hills of Linarès, upon the southern slope of the Sierra Morena, and in the district of the small town of Caujagar. Sometimes enormous masses of galena are extracted from the mines of Linarès. There are also mines of galena in Catalonia, Grenada, Murcia, and Almeira, the ore of the last locality being generally poor in silver. 12. The lead mines of Sweden are very argentiferous, and worked chiefly with a view to the silver. 13. The lead mines of Daouria are numerous and rich, lying in a transition limestone, which rests on primitive rocks ; their lead is neglected on account of the silver.

There have been a few lead mines in this country, which have been equally productive of silver. This was especially the case with the lead mines which were formerly worked around Combe Martin, and those at Beer-Alston in Devonshire. One of the most remarkable of recent examples, is a small mine known as Huel Florence near Tavistock, from which some lead ore has been sold at upwards of 90*l.* a ton, on account of the large quantity of silver it contained. At the conclusion of this article some tables will be given, showing the argentiferous character of the different lead producing districts of the United Kingdom.

Before proceeding to the consideration of the metallurgy of lead, a few brief notices of the history of lead mining may not be out of place.

As we have already stated, mining for lead must have been one of the earliest of man's subterranean labours, and at all periods of history we learn that lead mines have been worked. The Romans, especially, worked lead mines in Spain, and, after the conquest of this country, in many of our lead producing districts, especially in Cardiganshire, Shropshire, and Flintshire.

Lead mining appears to have been carried on from a very early period in Alston Moor, and some other of the northern districts. But in the west of England, lead mining must be regarded as a somewhat recent industry.

"Borlase mentions, in 1758, that lead mines had anciently and lately been worked in Cornwall, and that those most noted formerly, were Penrose, Penwerty, Trevascus, Belestian, and Guarnek (Garras). He states, that Penrose mines (near Helstone) had been wrought for about 200 years, that is, from about the middle of the sixteenth century, and that they had yielded tolerable profit within thirty years. The only lead mine worthy of note at work in his time, was at St. Issy, near Padstow. Pryce,

describes the lead ore of Garras, near Truro, to have been so argentiferous, that when wrought about 1720, it produced 100 oz. of silver in the ton of lead. Huel Pool, near Helstone, about 1790, yielded from 40 to 50 oz. of silver per ton of lead, and works were erected for extracting the silver. The lead ore of Wheal Rose contained 60 oz. of silver per ton.

In Devonshire, the Combe Martin and Beer Alston mines, have long been celebrated for their argentiferous lead ores. It is stated, that the produce of these mines was unusually great in the reigns of Edward I. and Edward II. In 1293, William de Wymundham accounted at the Treasury for 270 lbs. of silver raised in Devon. In 1294, it amounted to 521*l.* 10*s.* weight; and in 1294, to 704*l.* 3*s.* 1*d.* weight. In 1296, great profit is stated to have been derived from the Devon mines; and 360 miners were impressed out of Derbyshire and Wales to work in them. In 1360, a writ was issued, authorising certain persons to take up as many miners and workmen as should be necessary to work in the king's mines in Devon, allowing them reasonable wages according to the custom of the country; to arrest and imprison such as should resist, till they should give security to serve the king in the said mines, and to buy and provide timber at a competent price.

Henry, bishop of Winchester and cardinal of England, as one of the executors of John, duke of Bedford, who had a grant from the king of the gold and silver mines of Devon and Cornwall, rendered 26 lbs. and 2 oz. weight of pure silver as the 15th part of the pure silver raised in those counties from 15th December, 21st, to 16th August, 23rd of the same king's reign.

The Combe Martin mines were re-opened in the reign of Elizabeth. The working of these mines was strongly recommended to the Long Parliament in 1659; but Lysons observes that they do not appear to have been again worked until the close of that century, and then without success. In 1813 they were again opened and worked for 4 years, producing only 208 tons of ore in that time. In 1837 they were again worked, and we had an opportunity of observing that the previous mining operations presented every appearance of having formerly been very unskilfully managed. The two lodes near Beer-Alston have produced large quantities of argentiferous galena, often containing from 80 to 120 oz. of silver per ton of lead. According to Mr. Hitchings, the greatest quantity which occurred in that part of them named the South Hooe mine was 140 oz. of silver per ton of lead. In 1784 and 1785 the silver produce of these mines amounted to 6500 oz. From Huel Betsy, near Tavistock, which was re-opened in 1806, from 300 to 400 tons of lead, and from 4000 to 5000 oz. of silver were annually obtained. Lead mines were worked at a very early period in the Isle of Man, but the recent workings only date from the commencement of the present century. The mines of Cardiganshire were evidently worked by the Romans. In the reigns of Henry VII. and of Elizabeth they attracted much attention, and German miners were invited to work them.

The English lead-miners distinguish three different kinds of deposits of lead ore; *rake-veins*, *pipe-veins*, and *flat-veins*. The English word vein corresponds to the French term *filon*; but miners make use of it indifferently in England and France, to indicate all the deposits of this ore, adding an epithet to distinguish the different forms; thus, *rake-veins* are true veins in the geological acceptation of the word vein; *pipe-veins* are masses usually very narrow, and of oblong shape, most frequently parallel to the plane of the rocky strata; and *flat-veins* are small beds of ores interposed in the middle of these strata.

In the north of England, which, on account of its great preponderance in produce, we take as the basis of our description of lead mining, the ores are for the most part found in *veins* (*lodes* in Cornish) and flats. Although different names have been assigned to occasional varieties, the usual occurrence of lead ore is in rake veins, or direct running veins, usually named as *veins*, with some distinctive appellation prefixed, as, for example, Rampgill Vein, Hudgillburn Vein. Other veins, lying parallel, receive a similar prefix, with the addition of the words north, east, or south; but for the last named the word *sun* is often used; as, for instance, Hudgillburn Sun Vein, and 2nd and 3rd Sun Vein if further discoveries are made of other parallel veins. Considerable quantities of ore are also raised from horizontal extensions of portions of the vein called *flats*, and these are interposed between the strata adjacent to the vein.

Rake veins are the most common form in which lead ore occurs in Cumberland. They are in general narrower in the sandstone which covers the limestone, than in the calcareous beds. A thickness of less than a foot in the former becomes suddenly 3 or 4 feet in the latter; in the rich vein of Hudgillburn, the thickness is 17 feet in the *Great limestone*, while it does not exceed 3 feet in the overlying *Watersill* or sandstone. This influence exercised on the veins by the nature of the enclosing rock, is instructive; it determines at the same time almost uniformly their richness in lead ore, an observation similar to what has been made in other countries, especially in the veins

of Kongsberg in Norway. The Cumberland veins are constantly richer, the more powerful they are, in the portions which traverse the calcareous rocks, than in the beds of sandstone, and more particularly the schistose rocks. It is rare in the rock called *plate* (a solid slaty clay) for the vein to include any ore; it is commonly filled with a species of potter's earth. The upper calcareous beds are also in general more productive than the lower ones. In most of these mines, the veins were not worked till lately below the fifth calcareous bed (the four-fathom limestone), which is 307 yards beneath the millstone-grit; and as the first limestone stratum is 108 yards beneath it, it follows that the thickness of the part of the ground where the veins are rich in lead does not in general exceed 200 yards. It appears however that veins have been mined in the neighbourhood of Alston Moor, downwards to the eleventh calcareous stratum, or Tyne bottom limestone, which is 418 yards under the millstone-grit of the coal formation, immediately above the whin-sill; and that they have been followed above the first limestone stratum, as high as the grindstone sill, which is only 83 yards below the same stratum of millstone-grit; so that in the total thickness of the plumbiferous formation is there more than 336 yards. It has been asserted that lead veins have been traced even further down, into the *Memerby* scar limestone; but they have not been mined.

The greatest enrichment of a vein takes place commonly in the points where its two sides, being not far asunder, belong to the same rock; and its impoverishment occurs when one side is calcareous and the other a schistose clay. The minerals which most frequently accompany the galena, are carbonate of lime, fluate of lime, sulphate of baryta, quartz, and pyrites.

The *pipe veins* (*amas* in French), are seldom of great length; but some have a considerable width; their composition being somewhat similar to that of the rake veins. They meet commonly in the neighbourhood of the two systems, sometimes being in evident communication together; they are occasionally barren; but when a wide pipe-vein is metalliferous, it is said to be very productive.

The *flat veins*, or *strata veins*, seem to be nothing else than expansions of the matter of the vein between the planes of the strata; and contain the same ores as the veins in their vicinity. When they are metalliferous, they are worked along with the adjacent rake vein; and are productive to only a certain distance from that vein, unless they get enriched by crossing a rake vein. Some examples have been adduced of advantageous workings in *flat veins* in the *great limestone* of Cumberland, particularly in the mines of Coalcleugh and Nenthead. The *rake veins*, however, furnish the greater part of the lead which Cumberland and the adjacent counties send every year into the market.

The metalliferous limestone occupies, in Derbyshire, a length of about 25 miles from north-west to south-east, under a very variable breadth, which towards the south amounts to 25 miles. Castleton to the north, Buxton to the north-west, and Matlock to the south-east, lie nearly upon its limits. It is surrounded on almost all sides by the millstone grit which covers it, and which is, in its turn, covered by the coal strata. The nature of the rocks beneath the limestone is not known. In Cumberland the metalliferous limestone includes *a bed of trap*, designated under the name of *whinsill*. In Derbyshire the trap is much more abundant, and it is thrice interposed between the limestone. These two rocks constitute of themselves the whole mineral mass, through a thickness of about 550 yards, measuring from the millstone grit; only in the upper portion, that is near the millstone grit, there is a pretty considerable thickness of argillo-calcareous schists.

Four great bodies or beds of limestone are distinguishable, which alternate with three masses of trap, called toadstone. The lead veins exist in the calcareous strata, but disappear at the limits of the toadstone. It has, however, been ascertained that they recur in the limestone underneath. See VEINS.

METALLURGY OF LEAD.

Although lead forms an essential element in a large number of minerals, the ores of this metal are, strictly speaking, far from numerous. Of these the most important is sulphide of lead, or galena. This mineral, which possesses a metallic brilliancy, and has a lighter colour than metallic lead, presents, in its cleavage, all the variations from large facettes and laminæ indicating a cubic crystallisation to a most minutely granular structure. It is extremely brittle, and its powder presents a brilliant blackish-grey appearance.

The specific gravity of galena is 7·5 to 7·8, and its composition, when absolutely pure, is :—

Lead	86·55
Sulphur	13·45
	100·00

Galena is, however, but seldom found chemically pure, as, in addition to variable quantities of earthy impurities, it almost always contains a certain amount of silver. It is usually observed that galena presenting large facettes is less argentiferous than those varieties having a closer grain, and that finely granular steely specimens generally afford the largest amount of silver.

It would appear, from recent experiments, that the silver contained in the finely-granular varieties of galena often occurs in the form of sulphide of silver, mechanically intermixed, whilst in the more flaky descriptions of this ore, the sulphides of lead and silver are chemically combined.

Galena occurs in beds and veins, in granite, gneiss, clay-slate, limestone, and sandstone rocks.

In Spain it is found in the granite hills of Lanarès and elsewhere; at Freiberg in Saxony it occupies veins in gneiss; in the Harz, Bohemia, Cornwall, and many other localities, it is found in killas, or clay-slate. The rich deposits of Derbyshire, Cumberland, and the northern districts of England, are in the mountain limestone, whilst at Commern, near Aix-la-Chapelle, large quantities of this ore are found disseminated in the Bunter sandstone.

This mineral is frequently associated with blende, iron and copper pyrites, the carbonate and other ores of lead, and usually occurs in a gangue of sulphate of baryta, calc-spar, spathose iron, or quartz. It is also not unfrequently associated with fluor-spar.

The next most important ore of lead is the carbonate, which is a brittle mineral, of a white or greyish-white colour, having a specific gravity varying from 6·46 to 6·50. Its composition is, —

Carbonic acid - - - - - - - -	16·05
Oxide of lead - - - - - - - -	83·56
	99·61

Large quantities of this substance occur in the mines of the Mississippi Valley in the United States of America, where they were formerly thrown away as useless, but have since been collected and smelted. Vast deposits of this substance have also been found in the Bunter sandstone, near Düren, in Prussia, and at Freyung, in Bavaria. In the two latter localities it appears to form the cement holding together the granules of quartz, of which the sandstone principally consists. These ores, which yield from 14 to 20 per cent. of metal, do not readily admit of being concentrated by washing.

The sulphate of lead does not often occur in sufficient quantities to be employed as an ore of that metal. In appearance it is not unlike the carbonate, but may readily be distinguished from it by its not dissolving with effervescence in nitric acid.

Its specific gravity is from 6·25 to 6·30, and its composition : —

Sulphuric acid - - - - - - - -	25·65
Oxide of lead - - - - - - - -	74·05
	99·70

This ore of lead usually results from the oxidation of galena. At St. Martin's, near the Vega de Ribaddeo, in Spain, this mineral, more or less mixed with the phosphate of lead, is found in sufficient quantities to be made, on a small scale, the subject of an especial metallurgic treatment. Large quantities of sulphate of lead ores are also annually imported into this country from the mines in Australia. These ores contain on an average 35 per cent. of lead, and 35 oz. of silver to the ton of ore, together with a little gold.

Phosphate of lead, when crystallised, usually presents the appearance of hexagonal prisms, of a bright-green, brown, or yellowish colour. Its specific gravity varies from 6·5 to 7·1. This mineral is composed of a mixture of true phosphate of lead, phosphate of lime, chloride of lead, and fluoride of calcium, and usually contains about 78 per cent. of oxide of lead. In Spain, it occurs in botryoidal forms, in connection with the sulphate of the same metal, and is treated in blast furnaces for the lead it affords.

The other minerals containing lead seldom occur in sufficient quantities to be of much importance to the smelter, and may therefore be disregarded in the present article.

The extraction and mechanical preparation of ores is the business of the miner, and not of the metallurgist who receives them from the former freed as perfectly as possible from foreign matters.

The metallurgic processes, by the aid of which lead is obtained from galena, may be divided into two classes. The first of these is founded on the following reactions : — If one equivalent of sulphide of lead and two equivalents of the oxide of the same

metal are fused together, the result is three equivalents of metallic lead and one equivalent of sulphurous acid, which is evolved.

This reaction is represented by the following equation:—

$$PbS + 2PbO = 3Pb + SO^2.$$

When, on the other hand, one equivalent of sulphide of lead, and one equivalent of sulphate of lead are similarly treated, two equivalents of lead are obtained, and two equivalents of sulphurous acid gas evolved. Thus:—

$$PbS + PbO,SO^2 = 2Pb + 2SO^2.$$

The process, founded on the foregoing reactions, and which we will distinguish as the *method by double decomposition*, consists in roasting the galena in a reverberatory furnace until a certain amount of oxide and sulphate has been formed, and subsequently, after having intimately mixed the charge, and closed the doors of the furnace, causing the whole to enter into a state of fusion.

During this second stage of the operation, the reaction between the sulphides, sulphates, and oxides takes place, and metallic lead is eliminated. The roasting of the ore is, in some cases, conducted in the same furnace in which the fusion is effected, whilst in others two separate furnaces are employed.

The process by double decomposition is best adapted for the richer varieties of ore, and such as are least contaminated by siliceous or earthy impurities, and is consequently that which is almost universally employed for smelting the ores of this country.

By the second method which we will call the *process by affinity*, the ore is fused with a mixture of metallic iron, which by combining with the sulphur liberates the metallic lead. This reaction will be understood by reference to the following formula:—

$$PbS + Fe = Pb + FeS.$$

In practice, however, metallic iron is not always employed for this purpose; cast-iron is also frequently used, and in some instances the ores of iron and hammer slags are substituted, as are also tap-cinder and other secondary products containing a considerable percentage of this metal. None of these substances are, however, found to be so efficacious as metallic iron, since cast-iron requires to be decarburised before it can readily decompose the sulphide of lead, and the ores of iron require the introduction of various fluxes, and the consequent expenditure of an additional amount of fuel. In all cases, however, it is judicious to subject the ore to a preliminary roasting, in order to eliminate a portion of the sulphur, and thereby reduce the expenditure of iron, as well as to agglutinate the ore and render it better adapted for its subsequent treatment in the blast furnace.

We will not attempt to describe the different forms given to roasting furnaces employed for the ores treated by this process, but would remark that they frequently resemble the kilns used for the preparation of lime, whilst in some instances the ores are roasted in heaps interstratified with wood or other fuel.

The method of treating ore by *affinity* is particularly adapted to those varieties that contain a considerable amount of silica, since such minerals, if treated by double decomposition, would, by the formation of oxide of lead, give rise to silicates, from which it would be exceedingly difficult to extract the metal.

English process. Treatment by double decomposition. — Galena, if placed in a close vessel which protects it from the action of the air, and exposed to a gradually increasing temperature, becomes fused without the elimination of any lead taking place, but ultimately a portion of the sulphur is driven off, and a subsulphide is formed, which at a very elevated temperature is volatilised without change.

If, however, the vessel be uncovered, and the air allowed to act on its contents, oxygen combines with the sulphur, sulphurous acid is evolved, and the desulphuration of the mineral is slowly effected.

When galena is spread on the hearth of a reverberatory furnace, and is so placed as to present the largest possible amount of surface to oxidising influences, it will be found that the surface slowly becomes covered with a yellowish-white crust of sulphate of lead. The oxygen of the air, by combining with the two elementary bodies of which galena is composed, will evidently produce this effect. This is not, however, the only chemical change which takes place in the charge under these circumstances; oxide of lead is produced at the same time as the sulphate, or rather the formation of the oxide is prior to that of the sulphate.

In fact, during the first stage of the operation of roasting, sulphurous acid is evolved, the sulphur quits the lead, and a portion of that metal remains in a free state. This becomes oxidised by the air passing through the furnace, and subsequently a part of it combines with sulphuric acid, formed by the oxidation of sulphu-

rous acid, and sulphate of lead is the result. In this way, after the expiration of a certain period, both oxide and sulphate of lead are present in the furnace.

During the early period of the roasting, when the temperature of the furnace is not very elevated, the proportion of sulphate is larger than that of the oxide formed, but in proportion as the heat of the apparatus increases, the production of oxide becomes more considerable, whilst that of the sulphate diminishes.

The sulphate and oxide thus formed re-act in their turn on the undecomposed galena, whilst a portion of the latter, by combining with the sulphide of lead, gives rise to the formation of oxysulphide.

This last compound has no action on galena, except to dissolve it in certain proportions, but is readily decomposed by the aid of carbonaceous matter.

It is therefore evident that the addition of carbon, at this stage of the operation, will have the effect of reducing the oxide and oxysulphide of lead.

Every process then that has for its object the reduction of lead ores by double decomposition, comprises two principal operations. 1st. The reduction of galena, by the aid of heat and atmospheric air, to a mixture of sulphide, oxide, and sulphate, which mutually decompose each other, with the elimination of metallic lead. 2nd. The reduction of the oxysulphide by the addition of carbonaceous matter.

The reverberatory furnace. — The reverberatory furnace employed for the treatment of galena is composed, like all other furnaces of this description, of three distinct parts, the fire-place, the hearth, and the chimney.

The hearth has to a certain extent the form of a funnel, of which the lowest point is on the front side of the furnace immediately below the middle door. The molten metal descending from every side along the inclined bottom or sole, is collected in this receptacle, and is ultimately run off by means of a proper tap-hole. This tap-hole is, during the operation, closed by a pellet of clay.

The inclination of the hearth is more rapid in the vicinity of the fire-bridge than towards the chimney, in order that the liquid metal may not be too long exposed to the oxidising and volatilising influences of a current of strongly-heated air.

The dimensions given to these furnaces, as well as the weight of the charge operated on at one time, vary considerably in different localities, but in the north of England the following measurements are usually employed :— The fire-grate is 5 ft. 9 in. × 1 ft. 10 in., and the thickness of the fire-bridge 1 ft. 6 in.; the length of the sole is 9 ft., and its average width 7 ft. The depth of the tap is about 2 ft. 6 in. below the top of the inclined sole. The height of the roof at the fire-end may be 1 ft. 4 in., and at the other extremity 11 inches.

The introduction of the charge is in some cases effected by the doors of the furnace, whilst in other instances a hopper, placed over the centre of the arch, is made use of.

On the two sides of the furnace are placed three doors about 11 in. × 9 in., which are distinguished as 1, 2 and 3, counting from the fire-bridge end. The three doors on the one side are known as the front-doors, whilst those on the other side are called the back-doors. Immediately beneath the door on the front side of the furnace is situated the iron pan into which the molten lead is tapped off.

The bottom of this arrangement is in most cases composed of fire-bricks, covered by a layer of vitrified slags, of greater or less thickness. In order to form this bottom, the slags are introduced into the furnace, the doors closed, and the damper raised. An elevated temperature is thus quickly obtained, and as soon as the scoriæ have become sufficiently fused, they are, by means of rakes and paddles, made to assume the required form. The charge employed, as before stated, varies in almost every establishment. In the North, however, smaller charges are used than most other localities. At Newcastle, and in the neighbourhood, the charge varies from 12 to 14 cwt.; in Wales, and near Bristol, 21 cwt. charges are treated; whilst in Cornwall, charges of 30 cwt. are not unfrequently worked. The time required for smelting a charge varies with its weight and the nature of the ores, from 6 to 24 hours.

In some cases the ore is introduced raw into the furnace, whilst in others it undergoes a preliminary roasting previous to its introduction. Rich ores are generally smelted without being first calcined, but the poorer varieties, and particularly those which contain large quantities of iron pyrites, are, in most instances, subjected to roasting in a separate furnace.

In order to understand more clearly the operation of smelting in furnaces of this description, we will suppose that a charge has just been tapped off, and that, after thoroughly clearing the hearth, a fresh charge of raw ores has been introduced. During the first part of the operation of roasting, which usually occupies about two hours, the doors are taken off to admit free access of air, and also for the purpose of cooling the furnace, which has been strongly heated at the close of the preceding operation. No fuel is at this period charged upon the grate, since the heat of the furnace is of itself sufficient to effect the elimination of the first portions of sulphur.

The ore is carefully stirred, for the purpose of constantly presenting a fresh surface to oxidising influences, and when white fumes are no longer observed to pass off in large quantities, a little coal may be thrown on the grate, and the temperature gradually elevated until the charge becomes slightly clammy and adheres to the rake. When the roasting is considered as being sufficiently advanced, the smelter turns his attention to the state of the fire, taking care to remove the clinkers and get the grate into proper condition for the reception of a fresh supply of fuel. The furnace doors are now closed, and a strong heat is kept up for about a quarter of an hour, when the smelter examines the condition of his charge by removing one of the doors. If the operation is progressing satisfactorily, and the lead flowing freely and passing without obstruction into the tap, the firing is continued a little longer; but when the ores have been found to have taken fire, or are lying unevenly on the bottom of the furnace, the position of the charge is changed by the use of an iron paddle. During this operation the furnace becomes partially cooled, and the reduction of temperature thus obtained is frequently found to produce decompositions, which facilitate the reduction of the charge. In the case of extremely refractory ores this alternate heating and cooling of the furnace is sometimes almost indispensable, whilst, in other instances, their being once or twice raked over is all the manipulation that is required.

We will suppose that four hours have now elapsed since the charging of the furnace, and that the charge has run down the inclined sole towards the tap. The smelter now examines the condition of the scoriæ and adds a couple of shovelfuls of lime and three or four shovelfuls of small coals, the amount and relative proportions of these being regulated in accordance with the aspect of the slags. The charge is now, by means of proper tools, again raised to the breast of the furnace, and the firing continued until the charge has run down into the tap hole. The foreman now takes his rake and feels if any lumps remain in an unfused condition, and if he finds all to be in a fluid state he calls his assistant from the other side, and by the addition of a small quantity of lime and fine coal, makes the slag assume a pasty or rather doughy consistency. By the aid of his paddle he now pushes this compound up to the opposite side of the furnace, where it is drawn by an assistant through the back door into a trough containing water. Whilst the assistant is doing this the foreman is busily engaged in tapping off the metal into the iron pan in front of the furnace, from which, when sufficiently cooled, it is laded out into suitable moulds.

The total duration of the operation may be about six hours.

To build a furnace of the above description, 5000 common bricks, 2000 fire bricks, and 2½ tons of fire-clay are required. In addition to this must be reckoned the iron-work, the expense of which will be much influenced by the nature of the armatures employed and the locality in which the furnace is constructed.

The amount of fuel employed for the treatment of a ton of lead ore varies not only in relation to the richness of the mineral, but is also much influenced by the nature of the associated matrix and the calorific value of the fuel itself. The loss of metal experienced during the operation is mainly dependent on the richness of the ore treated and the skill and attention of the foreman.

In the North about 12 cwt. of coal are consumed in the elaboration of one ton of ore, and the loss of metal on 60 per cent. ore may be estimated at about 12 per cent., of which about 6½ per cent. is subsequently recovered from the slag and fumes. At a well-conducted smelting works, situated in the west of England, in which the average assay of the ores smelted during the year was 75½, the yield from the smelting furnaces was 68½ per cent., and the coal used per ton of ore was 13¾ cwts. The lead recovered from the slag and fumes amounted to 2¾ per cent., making the total yield of metal 71¼ per cent., and the loss on the assay produce 4½ per cent.

In this establishment the men are paid from 7*s.* 6*d.* to 12*s.* 6*d.* per ton of lead, in accordance with the nature of the ores operated on.

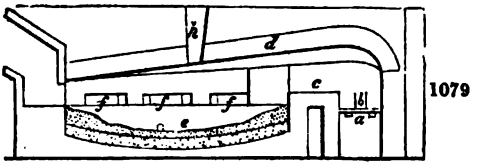
In one establishment the process before described is somewhat varied. The charge employed is 21 cwt. This is run down and tapped off at the expiration of 6 hours, and about 9 pigs of 1¼ cwt. each usually obtained. A second charge of 21 cwt. is then dropped in, and, as soon as it is roasted, mixed with the slags of the former operation. The whole is then run down in the ordinary way, the slags drawn and the lead tapped off in 9 hours. The produce of the second or double charge is from 14 to 15 pigs.

If the ores are difficult to flow, 16 to 16½ hours are required for the two charges. A small quantity of black slag from the slag hearth is employed for drying up.

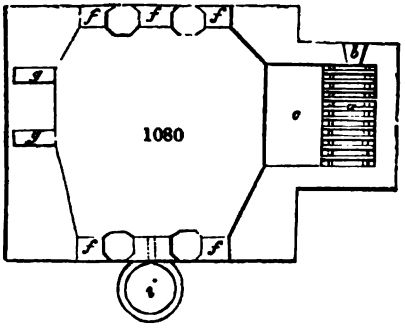
Figs. 1079, 1080, 1081, represent the reverberatory furnace at the Marquess of Westminster's lead smelting works, two miles from Holywell. The hearth is hollowed out below the middle door of the furnace; it slopes from the back and ends towards this basin. The distance from the lowest point of this concavity up to the sill of the door, is usually 24 inches, but it is sometimes a little less, according to the quality of the

ores to be smelted. This furnace has no hole for running off the slag, above the level of the tap hole for the lead, like the smelting furnace of Lea, near Matlock. A single chimney stalk serves for all the establishment; and receives all the flues of the various roasting and reducing furnaces. *Fig.* 1081 gives an idea of the distribution of these flues. *a a a*, &c. are the furnaces; *b*, the flues, 18 inches square; these lead from each furnace to the principal conduit *c*, which is five feet deep by 2½ wide; *d* is 6 feet deep by 3 wide; *e* is a round chamber 15 feet in diameter; *f* is a conduit, 7 feet high by 5 wide; *g* another, 6 feet high by 3 wide. The chimney at *h* has a diameter at bottom of 30 feet, at top of 12 feet, including the thickness of its sides, forming a truncated cone 100 feet high; whose base stands upon a hill a little way from the furnaces, and 62 feet above their level.

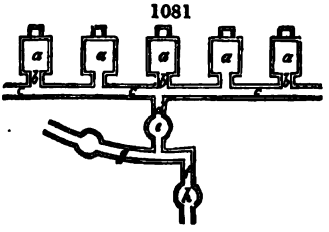
a, *figs.* 1079, 1080, is the grate; *b*, the door of the fire-place; *c*, the fire-bridge; *d*, the arched roof; *e*, the hearth; *f f f*, &c. the working doors; *g g*, flues running into one



1079



1080



1081

conduit, which leads to the subterranean condensing-chamber *e*, and thence to the general chimney; *h*, a hopper-shaped opening in the top of the furnace, for supplying it with ores.

This magnificent structure is not destined solely for the reduction of the ores, but also for dissipating all the vapours which might prove noxious to the health of the workpeople and to vegetation.

The ores smelted at Holywell are very refractory galenas, mixed with blende, calamine, pyrites, carbonate of lime, &c., but without any fluate of lime. They serve mutually as fluxes to one another. The coal is of inferior quality. The sole of each furnace is formed of slags obtained in the smelting, and they are all of one kind. In constructing it, 7 or 8 tons of these slags are first thrown upon the brick area of the hearth; are made to melt by a brisk fire, and in their stiffening state, as they cool, they permit the bottom to be sloped and hollowed into the desired shape. Four workmen, two at each side of the furnace, perform this task.

The ordinary charge of ore for one smelting operation is 20 cwt., and it is introduced through the hopper. An assistant placed at the back doors spreads it equally over the whole hearth with a rake; the furnace being meanwhile heated only with the declining fire of a preceding operation. No regular fire is made during the first two hours, but a gentle heat merely is kept up by throwing one or two shovelfuls of small coal upon the grate from time to time. All the doors are closed, and the register-plate of the chimney lowered.

The outer basin in front of the furnace is at this time filled with the lead derived from a former process, the metal being covered with slags. A rectangular slit above the tap hole is left open, and remains so during the whole time of the operation, unless the lead should rise in the interior basin above the level of that orifice; in which case a little mound must be raised before it.

The two doors in front furthest from the fire being soon opened, the head-smelter throws in through them, upon the sole of the furnace, the slags swimming upon the

bath of lead, and a little while afterwards he opens the tap-hole, and runs off the metallic lead reduced from these slags. At the same time his assistant turns over the ore with his paddle, through the back doors. These being again closed, while the above two front doors are open, the smelter throws a shovelful of small coal or coke cinder upon the lead bath, and works the whole together, turning over the ore with the paddle or iron oar. About three quarters of an hour after the commencement of the operation, he throws back upon the sole of the hearth the fresh slags which then float upon the bath of the outer basin, and which are mixed with coaly matter. He next turns over these slags, as well as the ore with the paddle, and shuts all the doors. At this time the smelter lades off the lead into the pig-moulds.

The assistant now turns over the ore once more through the back doors. A little more than an hour after the operation began, a quantity of lead proceeding from the slag last remelted, is run off by the tap; being usually in such quantity as to fill one half of the outer basin. Both the workmen then turn over the ore with the paddles, at the several doors of the furnace. Its interior is at this time of a dull red heat; the roasting being carried on rather by the combustion of the sulphurous ingredients, than by the action of the small quantity of coal in the grate. The smelter, after shutting the front doors, with the exception of that next the fire-bridge, lifts off the fresh slags lying upon the surface of the outside bath, drains them, and throws them back into the furnace.

An hour and a half after the commencement, the lead begins to ooze out in small quantities from the ore; but little should be suffered to flow before two hours have expired. About this time the two workmen open all the doors, and turn over the ore, each at his own side of the furnace. An hour and three quarters after the beginning, there are few vapours in the furnace, its temperature being very moderate. No more lead is then seen to flow upon the sloping hearth. A little coal being thrown into the grate to raise the heat slightly, the workmen turn over the ore, and then close all the doors.

At the end of two hours, the *first fire* or roasting being completed, and the doors shut, the register is to be lifted a little, and coal thrown upon the grate to give the *second fire*, which lasts during 25 minutes. When the doors are now opened, the inside of the furnace is of a vivid red colour, and the lead flows down from every side towards the inner basin. The smelter with his rake or paddle pushes the slags upon that basin back towards the upper part of the sole, and his assistant spreads them uniformly over the surface through the back doors. The smelter next throws in by his middle door, a few shovelfuls of quicklime upon the lead bath. The assistant meanwhile for a quarter of an hour works the ore and the slags together through the three back doors, and then spreads them out, while the smelter pushes the slags from the surface of the inner basin back to the upper part of the sole. The doors being now left open for a little, while the interior remains in repose, the metallic lead, which had been pushed back with the slags, flows down into the basin. This occasional *cooling* of the furnace is thought to be necessary for the better separation of the products, especially of the slags from the lead bath.

In a short time the workmen resume their rakes, and turn over the slags along with the ore. Three hours after the commencement, a little more fuel is put into the grate, merely to keep up a moderate heat of the furnace during the puddling. After three hours and ten minutes, the grate being charged with fuel for the *third fire*, the register is completely opened, the doors are all shut, and the furnace is left in this state for three quarters of an hour. In nearly four hours from the commencement, all the doors being opened, the assistant levels the surfaces with his rake, in order to favour the descent of any drops of lead; and then spreads the slags, which are pushed back towards him by the smelter. The latter now throws in a fresh quantity of lime, with the view not merely of covering the lead bath and preventing its oxidation, but of rendering the slags less fluid.

Ten minutes after the third fire is completed, the smelter puts a new charge of fuel on the grate, and shuts the doors of the furnace to give it the *fourth fire*. In four hours and forty minutes from the commencement, this fire being finished, the doors are opened, the smelter pierces the tap-hole to discharge the lead into the outer basin, and throws some quicklime upon the slags in the inner basin. He then pushes the slags thus *dried up* towards the upper part of the hearth, and his assistant rakes them out by the back doors.

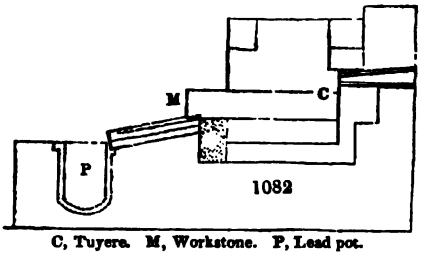
The whole operation of a *smelting shift* takes about four hours and a half, or at most five hours, in which four periods may be distinguished.

1. The *first fire* for roasting the ores requires very moderate firing, and lasts two hours.

2. The *second fire*, or smelting, requires a higher heat, with shut doors; at the end the slags are *dried up* with lime, and the furnace is also allowed to cool a little.

3, 4. The last two periods, or the *third and fourth fires*, are likewise two smeltings or foundings, and differ from the first only in requiring a higher temperature. The heat is greatest in the last. The form and dimensions of the furnace are calculated to cause a uniform distribution of heat over the whole surface of the hearth. Sometimes billets of green wood are plunged into the metallic lead of the outer basin, causing an ebullition which favours the separation of the slags, and consequently the production of a purer lead; but no more metallic metal is obtained.

Ten cwts. of coal are consumed at Holywell in smelting one ton of the lead-ore *schlich* or sludge; but at Grassington, near Skipton in Yorkshire, with a similar furnace worked with a slower heat, the operation taking from seven hours to seven hours and a half, instead of five, only 7½ cwt. of coal are consumed. But here the ores are less refractory, have the benefit of fluor spar as a flux, and are more exhausted of their metal, being smelted upon a less sloping hearth.



C, Tuyere. M, Workstone. P, Lead pot.

The ore-hearth.—This furnace, called by the French *fourneau écossais*, is from 22 to 24 inches in height and 1 foot by 1½ in area inside; but its horizontal section, always rectangular, varies much in its dimensions at different levels, as shown in *fig.* 1082.

Treatment of lead ores by the Scotch furnace or ore-hearth.—This furnace is generally employed in the counties of Northumberland, Cumberland, and Durham, for the smelting of lead ores, which were formerly carried to them without any preparation, but they are now often exposed to a preliminary calcination. The roasted ore yields in the Scotch furnace a more considerable product than the crude ore, because it forms in the furnace a more porous mass, and at the same time *it works drier*, to use the founder's expression; that is, it allows the stream of air impelled by the blast to diffuse itself more completely across the matters contained in the furnace.

In proceeding to smelt by means of an ore-hearth, two workmen are required to be in attendance from the beginning to the end of each smelting shift, the duration of which is from 12 to 15 hours. The first step in commencing a smelting shift is to fill up the hearth-bottom, and space below the workstone with *peats*, placing one already kindled before the nozzle of the bellows. The powerful blast very soon sets the whole in a blaze, and by the addition of small quantities of coal at intervals, a body of fire is obtained, filling the hearth. Roasted ore is now put upon the surface of the fire, between the forestone and pipestone, which immediately becomes heated red hot and reduced; the lead from it sinking down and collecting in the hearth bottom. Other portions of ore of 10 or 12 lbs. each are introduced from time to time, and the contents of the hearth are stirred and kept open, being occasionally drawn out and examined upon the workstone, until the hearth bottom becomes full of lead. The hearth may now be considered in its regular working state, having a mass of heated fuel, mixed with partly fused and semi-reduced ore, called *Brouze*, floating upon a stratum of melted lead. The smelting shift is then regularly proceeded with by the two workmen, as follows:—The fire being made up, a stratum of ore is spread upon the horizontal surface of the *brouze*, and the whole suffered to remain exposed to the blast for the space of about five minutes. At the end of that time, one man plunges a poker into the fluid lead, in the hearth bottom below the *brouze*, and raises the whole up, at different places, so as to loosen and open the brouze, and in doing so, to pull a part of it forwards upon the workstone, allowing the recently added ore to sink down into the body of the hearth. The poker is now exchanged for a shovel, with a head 6 inches square, with which the brouze is examined upon the workstone, and any lumps that may have been too much fused, broken to pieces; those which are so far agglutinated by the heat, as to be quite hard, and further known by their brightness, being picked out, and thrown aside, to be afterwards smelted in the slag hearth. They are called "grey slags." A little slaked lime, in powder, is then spread upon the brouze, which has been drawn forward upon the workstone, if it exhibit a pasty appearance; and a portion of coal is added to the hearth, if necessary, which the workman knows by experience. In the mean time, his fellow workman, or shoulder fellow, clears the opening, through which the blast passes into the hearth, with a shovel, and places a peat immediately above it, which he holds in its proper situation, until it is fixed, by the return of all the brouze, from the workstone into the hearth. The fire is made up again into the shape before described, a stratum of fresh ore spread upon the part, and the operation of stirring, breaking the lumps upon the

workstone, and picking out the hard slags repeated, after the expiration of a few minutes, exactly in the same manner. At every stirring a fresh peat is put above the nozzle of the bellows, which divides the blast, and causes it to be distributed all over the hearth; and as it burns away into light ashes, an opening is left for the blast to issue freely into the body of the brouze. The soft and porous nature of dried peat renders it very suitable for this purpose; but, in some instances, where a deficiency of peats has occurred, blocks of wood of the same size have been used with little disadvantage. As the smelting proceeds, the reduced lead, filtering down through all parts of the brouze into the hearth bottom, flows through the channel, out of which it is laded into a proper mould, and formed into pigs.

The principal particulars to be attended to in managing an ore-hearth properly during the smelting shift, are these: First. — It is very important to employ a proper blast, which should be carefully regulated, so as to be neither too weak, nor too powerful. Too weak a blast would not excite the requisite heat to reduce the ore, and one too powerful has the effect of fusing the contents of the hearth into slags. In this particular no certain rules can be given; for the same blast is not suitable for every variety of ore. Soft free-grained galena, of great specific gravity, being very fusible, and easily reduced, requires a moderate blast; while the harder and lighter varieties, many of which contain more or less iron, and are often found rich in silver, require a blast considerably stronger. In all cases, it is most essential, that the blast should be no more than sufficient to reduce the ore, after every other necessary precaution is taken in working the hearth. Second. — The blast should be as much divided as possible, and made to pass through every part of the brouze. Third. — The hearth should be vigorously stirred, at due intervals, and part of its contents exposed upon the workstone; when the partially fused lumps should be well broken to pieces, as well as those which are further vitrified, so as to form slags, carefully picked out. This breaking to pieces, and exposure of the hottest part of the brouze upon the workstone, has a most beneficial effect in promoting its reduction into lead; for the atmospheric air immediately acts upon it, and, in that heated state, the sulphur is readily consumed, or converted into sulphurous acid, leaving the lead in its metallic state; hence it is that the reduced lead always flows most abundantly out of the hearth immediately after the return of the brouze, which has been spread out and exposed to the atmosphere. Fourth.—The quantity of lime used should be no more than is just necessary to thicken the brouze sufficiently; as it does not in the least contribute to reduce the ore by any chemical effect: its use is merely to render the brouze less pasty, if, from the heat being too great, or from the nature of the ore, it has a disposition to become very soft. Fifth.— Coal should be also supplied judiciously; too much unnecessarily increasing the bulk of the brouze, and causing the hearth to get too full.

When the ore is of a description to smelt readily, and the hearth is well managed in every particular, it works with but a small quantity of brouze, which feels dry when stirred, and is easily kept open and permeable to the blast. The reduction proceeds rapidly with a moderate degree of heat, and the slags produced are inconsiderable; but, if in this state, the stirring of the brouze and exposure upon the workstone are discontinued, or practised at longer intervals, the hearth quickly gets too hot, and immediately begins to agglutinate together; rendering evident the necessity of these operations to the successful management of the process. It is not difficult to understand why these effects take place, when it is considered, that in smelting by means of the ore-hearth, it is the oxygen of the blast and of the atmosphere which principally accomplishes the reduction; and the point to be chiefly attended to consists in exposing the ore to its action, at the proper temperature, and under the most favourable circumstances. The importance of having the ore free from impurities is also evident; for the stony or earthy matter it contains impedes the smelting process, and increases the quantity of slags. A very slight difference of composition of perfectly dressed ore may readily be understood to affect its reducibility; and hence it is, that ore from different veins, or the same vein in different strata, as before observed, is frequently found to work very differently when smelted singly in the hearth. It happens, therefore, that with the best workmen, some varieties of ore require more coal and lime, and a greater degree of heat than others; and it is for this reason that the forestone is made movable, so as either to answer for ore which works with a large or a small quantity of brouze.

It has been stated that the duration of a smelting shift is from 12 to 15 hours, at the end of which time, with every precaution, the hearth is apt to become too hot, and it is necessary to stop for some time, in order that it may cool. At mills where the smelting shift is 12 hours, the hearths usually go on 12 hours, and are suspended 5; four and a half or five bings* of ore (36 to 40 cwt.) are smelted during a shift, and the

* 1 bing=8 cwts.

two men who manage the hearth work each four shifts per week; terminating their week's work at 3 o'clock on Wednesday afternoon. They are succeeded by two other workmen, who also work four 12-hour shifts; the last of which they finish at 4 o'clock on Saturday. In these eight shifts, from 36 to 40 bings of ore are smelted, which, when of good quality, produce from 9 to 10 fodders* of lead. At other mills where the shift is 14 or 15 hours, the furnace is kindled at 4 o'clock in the morning, and worked until 6 or 7 in the evening each day, six days in the week; during this shift, 5 or 5½ bings of ore are smelted, and two men at one hearth, in the early part of each week, work three such shifts, producing about 4 fodders of lead — two other men work each 3 shifts in the latter part of the week, making the total quantity smelted per week, in one hearth, from 30 to 33 bings.

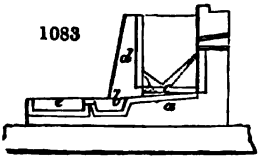
Hearth-ends and Smelter's fume. — In the operation of smelting, as already described, it happens that particles of unreduced and semi-reduced ore are continually expelled from the hearth, partly by the force of the blast, but principally by the decrepitation of the ore on the application of heat. This ore is mixed with a portion of the fuel and lime made use of in smelting, all of which are deposited upon the top of the smelting hearth, and are called hearth-ends. It is customary to remove the hearth-ends from time to time, and deposit them in a convenient place until the end of the year, or some shorter period, when they are washed to get rid of the earthy matter they may contain, and the metallic portion is roasted at a strong heat, until it begins to soften and cohere into lumps, and afterwards smelted in the ore-hearth, exactly in the same way as ore undergoing that operation for the first time, as already described.

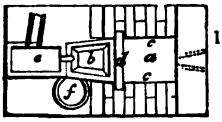
It is difficult to state what quantity of hearth-ends are produced by the smelting of a given quantity of ore, but in one instance the hearth-ends produced in smelting 9751 bings, on being roasted and reduced in the ore-hearth, yielded of common lead 315 cwt., and the grey slags separated in this process gave, by treatment in the slag-hearth, 47 cwt. of slag lead; making the total quantity of lead 362 cwt., which is at the rate of 3 cwt. 2 qrs. 23 lbs. from the smelting of 100 bings of ore.

Slag-hearth. — The various slags obtained from the different operations of lead smelting are divided into two classes. Those which do not contain a sufficient amount of metal to pay for further treatment are thrown away as useless, whilst those in which the percentage of lead is sufficiently large are treated by the slag-hearth.

Figs. 1083, 1084 represent a slag-hearth, the *fourneau à manche* (elbow furnace) of the French, and the *krummofen* (crooked furnace) of the Germans; such as is used at Alston Moor, in Cumberland, for the reduction of the lead-slag. It resembles the Scotch furnace. The shaft is a parallelopiped, whose base is 26 inches by 24 inches in area inside, and whose height is 3 feet; the sole-plate *a*, of cast iron, slopes slightly

1083





1084

down to the basin of reception or the fore-hearth *b*. Upon both of the long sides of the sole-plate there are cast iron beams, called *bearers*, *c c*, of great strength, which support the side walls built of a coarse grained sandstone, as well as the cast iron plate *d* (*fore-stone*), which forms the front of the shaft. This stands 7 inches off from the sole-plate, leaving an empty space between them. The back side is made of cast iron, from the sole-plate to the horizontal tuyère in its middle; but above this point it is made of sandstone. The tuyère is from 1½ to 2 inches in diameter. In front of the fore-hearth *b*, a cistern *e* is placed, through which water continually flows, so that the slags which spontaneously overflow the fore-hearth may become inflated and divided, whereby the lead disseminated through them may be readily separated by washing. The lead itself flows from the fore-hearth *b*, through an orifice, into an iron pot *f*, which is kept over a fire. The metal obtained from this slag-hearth is much less pure than that extracted directly from the ore.

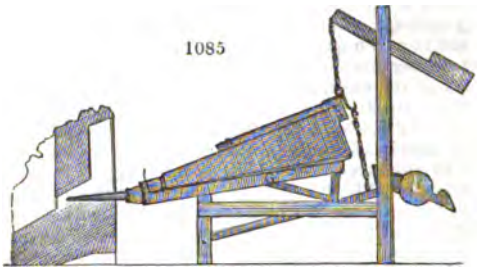
The whole bottom of the furnace is filled to a height of 17 inches, that is, to within 2 or 3 inches of the tuyère, with the rubbish of coke reduced to coarse powder and beat strongly down. At each *smelting shift*, this bed must be made anew, and the interior of the furnace above the tuyère repaired, with the exception of the front, consisting of cast iron. In advance of the furnace there is a basin of reception, which is also filled with coke rubbish. Farther off is the pit, full of water, replenished by a cold

* 1 fodder = 21 cwts.

stream, which incessantly runs in through a pipe. The scoriæ, in flowing out of the furnace, pass over the coke bed in the basin of reception, and then fall into the water, whose coolness makes them fly into small pieces, after which they are easily washed, so as to separate the lead that may be entangled among them.

These furnaces are urged sometimes by fans or by wooden bellows, *fig.* 1085. But at the smelting works of Lea, near Matlock, the blowing-machine consists of two casks, which move upon horizontal axes. Each of these casks is divided into two equal parts by a fixed plane that passes through its axis, and is filled with water to a certain height. The water of one side communicates with that of the other by an opening in the lower part of the division. Each cask possesses a movement of oscillation, produced by a rod attached to a crank of a bucket-wheel. At each demi-oscillation, one of the compartments, being in communication with the external air, is filled; whilst the other, on the contrary, communicates with the nozzle, and supplies wind to the furnace.

1085



Instead of being blown by a cold blast, these furnaces are sometimes supplied with heated air. When smelting with cold air, it is often found difficult to proportion the quantity of slag or other substance operated on, so as to preserve the nose or cone of slag which forms at the end of the tuyère from growing too long, to the prejudice of the operation. When the substance operated on is poor for metal, and very refractory, it frequently happens that the smelter is obliged to break the nose, or introduce some very fusible substance in order to melt it off. By the introduction of hot air this inconvenience is removed, since by increasing or lowering the temperature of the blast, the nose may be allowed to lengthen or shorten, according as the nature of the slags may require. The temperature found to answer best is from 250° to 300° Fahr.; since when it is heated to from 500° to 600°, it is found impossible to form a nose of sufficient length to convey the blast to the front of the hearth, and therefore the back, which is expensive to rebuild, is quickly destroyed.

The advantage to be derived from the use of the hot blast will be evident, from the result of two experiments which were tried some years since.

Twenty-eight tons of slag smelted with cold blast consumed 392 cubic feet of air per minute.

Labour cost - - - - - - - -	£3	7	8
Coke, 7 tons, at 24*s.* 6*d.* - - - - - -	8	11	6
Total	£11	19	2

Thirty-five tons of similar slag smelted with hot blast consumed 300 cubic feet of air per minute.

Labour cost - - - - - - - -	£3	7	8
Coke, 5 tons, 17 cwt., at 24*s.* 6*d.* - - -	7	3	4
Turf for heating air, 11 loads, 1*s.* 8*d.* - -	0	18	4
Total	£11	9	4

From which it will be seen that, with one-quarter part less air, a quarter part more slag was melted per week, and a saving of expense of nearly 10*s.* effected.

The loss of lead experienced in smelting by the slag hearth, is, however, very great, even under the most favourable circumstances; and it has, consequently, of later years been gradually superseded by the Castilian furnace, which will be shortly described. Many large and well-conducted establishments still however continue to employ the slag hearth, and when well constructed and skilfully managed, the loss arising from volatilisation may be considerably reduced.

Castilian furnace. — Within the last few years a blast furnace has been introduced into the lead works of this country, which possesses great advantages over every other description of apparatus which has been hitherto employed for the treatment of lead ores of low produce. This apparatus, although first employed in Spain, was invented by an Englishman (Mr. W. Goundry), who was employed in the reduction of rich slags in the neighbourhood of Carthagena.

This furnace is circular, usually about 2 feet 4 inches, or 2 feet 6 inches in

diameter, and is constructed of the best fire-bricks, so moulded as to fit together, and allow all the joints to follow the radii of the circle described by the brick work. Its usual height is 8 feet 6 inches, and the thickness of the masonry invariably 9 inches. In this arrangement the breast is formed by a semi-circular plate of cast-iron, furnished with a lip for running off the slag, and has a longitudinal slot, in which is placed the tapping-hole.

On the top of this cylinder of brickwork a box-shaped covering of masonry is supported by a cast-iron framing, resting on four pillars, and in this is placed the door for feeding the furnace, and the outlet by which the various products of combustion escape to the flues. The lower part of this hood is fitted closely to the body of the furnace, whilst its top is closed by an arch of 4½ inch brickwork laid in fire-clay. The bottom is composed of a mixture of coke-dust and fire-clay, slightly moistened, and well beaten to the height of the top of the breast-pan, which stands nearly 3 feet above the level of the floor. Above the breast-pan is an arch, so turned as to form a sort of niche, 18 inches in width, and rather more than 2 feet in height.

When the bottom has been solidly beaten, up to the required height, it is hollowed out so as to form an internal cavity, communicating freely with the breast-pan, which is filled with the same material and subsequently hollowed out to a depth slightly below the level of the internal cavity. The blast is supplied by three water tuyères, 3 inches in diameter at the smaller end, 5½ inches at the larger, and 10 inches in length. Into these the nozzles are introduced, by which a current of air is supplied by means of a fan or ventilator, making about 800 revolutions per minute. The blast may be conveniently conducted to the nozzles through brick channels formed beneath the floor of the smelting house.

The ores treated in this furnace ought never to contain more than 30 per cent. of metal, and when richer, must be reduced to about this tenure by the addition of slags and other fluxes. In charging this apparatus, the coke and ore are supplied stratum super stratum, and care must be taken so to dispose the coke as not to heat too violently the brickwork of the furnaces. In order to allow the slags which are produced to escape freely into the breast-pan, a brick is left out of the front of the furnace at the height of the fore-hearth, which, for the purpose of preventing the cooling of the scoriæ, is kept covered by a layer of coke-dust or cinders. From the breast-pan the slags flow constantly off over a spout into cast-iron waggons, where they consolidate into masses, having the form of truncated pyramids, of which the larger base is about 2 feet square. As soon as a sufficient amount of lead is accumulated in the bottom of the furnace, it is let off into a lateral lead-pot, by removing the clay-stopper of the tap-hole situated in the slot of the breast-pan, and after being properly skimmed it is laded into moulds. When in addition to lead the ore treated likewise contains a certain portion of copper, this metal will be found in the form of a matt floating on the surface of the leaden bath. This, when sufficiently solidified, is removed, and after being roasted is operated on for the copper it contains.

The waggons in which the liquid slag runs off, are frequently made to traverse small railways, by which, when one mass has been removed, its place may readily be supplied by an empty waggon. When nearly cold the casings of the waggons are turned over and the blocks of slag easily made to drop out. In addition to the facility for transport obtained in this way, one of the great advantages obtained by this method of manipulation arises from the circumstance that should the furnaces at any time run lead or matt, without its being detected by the smelter, the whole of it will be collected at the bottom of the block, from which, when cold, it may be readily detached.

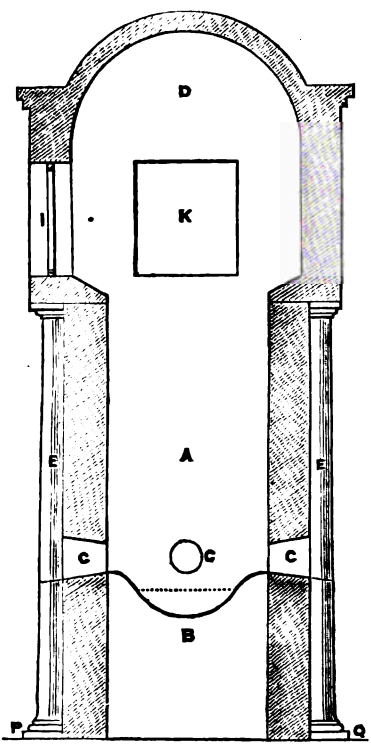
In working these furnaces, care must be taken to prevent flame from appearing at the tunnel-head, since, provided the slags are sufficiently liquid, the cooler the apparatus is kept the less will be the loss of metal through volatilisation. In addition to the greatest attention being paid to the working of the furnace, it is necessary, in order to obtain the best results, that all establishments in which this apparatus is employed should be provided with long and capacious flues, in which the condensation of the fumes takes place, previous to arriving at the chimney-shaft. These flues should be built at least three feet in width, and six feet in height, so as readily to admit of being cleaned, and are often made of several thousand yards in length. The value of the fumes, so condensed, amounts to many hundreds, and in some instances thousands per annum.

In order to be advantageously worked in these furnaces, the ores should be first roasted, and subsequently agglomerated into masses, which, after being broken into fragments, of about the size of the fist, and mixed with the various fluxes, are charged as before described.

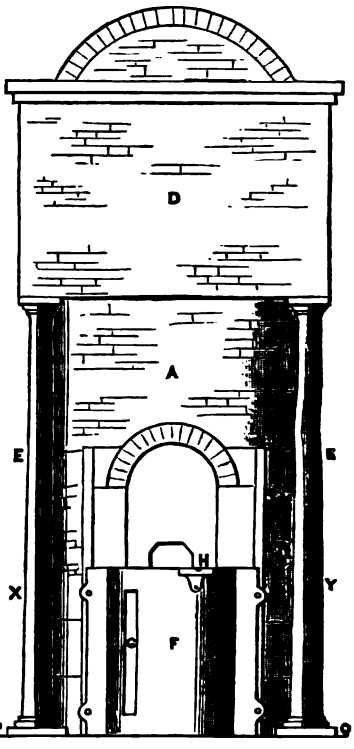
In an establishment in which the average assay produce of the roasted ore for lead

is 42¼ths, the furnace yield is 38½ths, and the weight of coke employed to effect the reduction 22 per cent. of the roasted ore operated on. The mixture charged into the furnace, in this instance, is composed of 100 parts of roasted ore, 42 parts of slags from a previous operation, 8 parts of scrap iron, and 7 parts of limestone. Each furnace works off about seven tons of roasted ore in the course of 24 hours; the weight of slags run off is about double that of the lead obtained, and the matt removed from the surface of the pan is nearly 5 per cent. of the lead produced. The ores treated in this establishment consist of galena, much mixed with spathose iron, and are therefore somewhat refractory. A furnace of this kind requires for its construction about 1000 segmental fire-bricks, and the same number of ordinary fire-bricks of second quality.

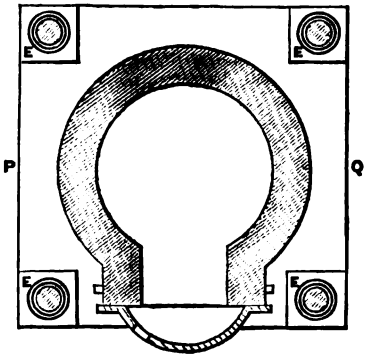
1086



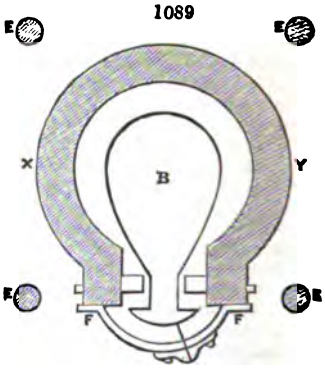
1087



1088



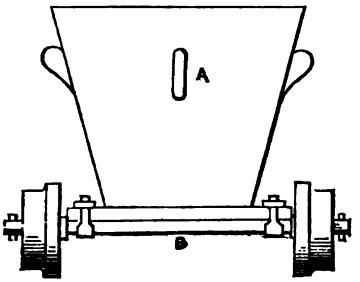
1089



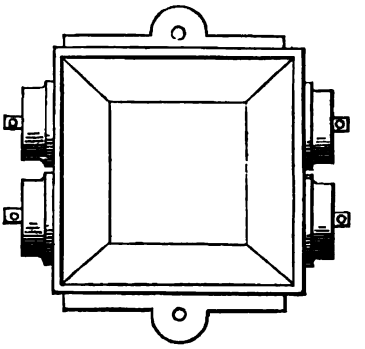
Figs. 1086, 1087, 1088, and 1089 represent respectively a vertical section, an elevation, a ground plan, and an horizontal section of a Castilian furnace. The section *fig.* 1089 is on the line X Y, *fig.* 1087. A is the body of the furnace, B, the bottom composed of a mixture of coke-dust and fire-clay; C C C, the tuyères; D, the rectangular covering of masonry; E E E E, cast iron pillars; F, the breast-pan; G, slot for tapping hole; H, lip of breast-pan; I, feeding door; K, flue-hole; P, Q, ground line.

Figs. 1090, 1091 are the slag-waggons, A being a movable case without a bottom, and B a strong cast-iron plate running on four wheels.

1090



1091



The desulphuration of the ores to be treated in these furnaces may be effected either by the aid of an ordinary reverberatory roasting furnace, or in heaps, or properly constructed kilns.

The kilns best adapted for this purpose consist of rectangular chambers, having an arched roof, and provided with proper flues for the escape of the evolved gases, as well as a wide door for charging and withdrawing the ore to be operated on.

Each of these chambers is capable of containing from 25 to 30 tons of ore, and in order to charge it a layer of faggots and split wood is laid on the floor, and this, after having been covered by a layer of ore about two feet in thickness, is ignited, care being at the same time taken to close, by means of loose brick-work, the opening of the door to the same height. When this first layer has become sufficiently ignited, a fresh stratum of ore, mixed with a little coal or charcoal, is thrown upon it, and when this layer has in its turn become sufficiently heated, more ore is thrown on. In this way more ore is from time to time added, until the kiln has become full, when the orifice of the doorway is closed by an iron plate, and the operation proceeds regularly and without further trouble until the greater portion has become eliminated. This usually happens at the expiration of about four weeks from the time of first ignition, and the brick-work front is then removed, and the ores broken out, and after being mixed with proper fluxes, passed through the blast furnace.

The proportion of wood necessary for the roasting of a ton of ore by this means must necessarily depend on the composition of the minerals operated on; but with ores of the description above-mentioned, and in a neighbourhood where wood is moderately cheap, the desulphuration may be effected at a cost of about 5*s.* per ton.

Calcining.—The lead obtained by the various processes above described generally contains a sufficient amount of silver to render its extraction of much importance; but, in addition to this, it is not unfrequently associated with antimony, tin, copper, and various other impurities, which require to be removed before the separation of the silver can be effected.

This operation consists in fusing the hard lead in a reverberatory furnace of peculiar construction, and allowing it to remain, when in a melted state, exposed to the oxidising influences of the gases passing through the apparatus. By this treatment the antimony, copper, and other impurities become oxidised, and on rising to the surface of the metallic bath are skimmed off, and removed with an iron rake. The hearth of the furnace in which this operation is conducted consists of a large cast-iron pan, which may be 10 feet in length, 5 feet 6 inches in width, and 10 inches in depth. The fire-place, which is 1 foot 8 inches in width, has a length equal to the width of the pan, and is separated from it by a fire-bridge 2 feet in width. The height of the arch at the bridge end is 1 foot 4 inches above the edge of the pan, whilst at the outer extremity it is only about 8 inches.

The lead to be introduced into the pan is first fused in a large iron pot fixed in

brick-work at the side of the furnace, and subsequently laded into it through an iron gutter adapted for that purpose. The length of time necessary for the purification of hard lead obviously depends on the nature and amount of the impurities which it contains; and, consequently, some varieties will be sufficiently improved at the expiration of twelve hours, whilst in other instances it is necessary to continue the operation during three or four weeks. The charge of hard lead varies from eight to eleven tons.

When the metal is thought to be in a fit state for tapping, a small portion taken out with a ladle, and poured into a mould used for this purpose is found on cooling to assume at the surface a peculiar crystalline appearance, which when once seen is readily again recognised. As soon as this appearance presents itself an iron plug is withdrawn from the bottom of the pan, and the lead run off into an iron pan, from which it is subsequently laded into moulds.

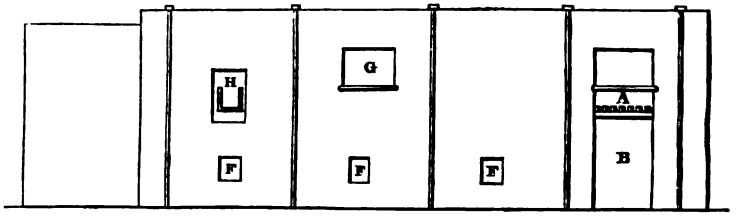
The items of cost attending the calcination of one ton of hard Spanish lead in the north of England are about as follows: —

	s.	d.
Wages	1	11·2
Coals, 2·7 cwt	0	4·7
Repairs, &c.	0	0·5
	2	4·4

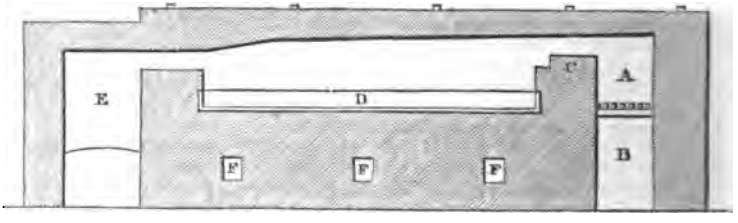
The construction of a furnace of this description requires 5000 common bricks, 3,500 fire-bricks, and 2 tons of fire clay.

Figs. 1092 and 1093 represent an elevation and vertical section of the calcining

1092

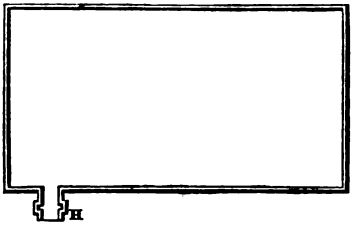


1093



furnace. A is the fire-place; B, ash-pit; C, fire-bridge; D, cast iron pan; E, flue; F F F, channels for allowing the escape of moisture; G, one of the working doors: H, spout for running off calcined metal. *Fig.* 1094 represents the pan removed from the masonry, and shows a groove in the lip for the introduction of a sheet-iron dam, tightened with moistened bone-ash for keeping in the fused metal.

1094

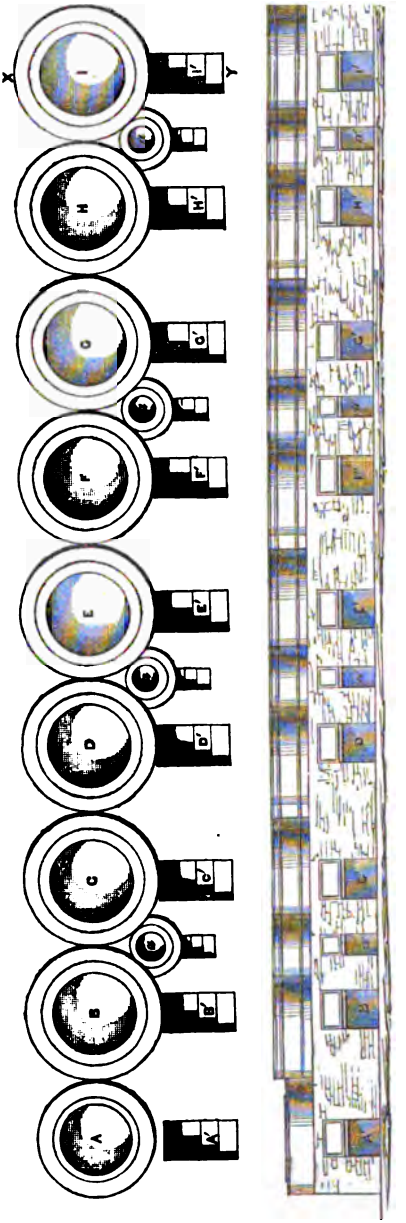


In the more modern furnaces of this description, the corners are usually rounded to prevent breakage from expansion, whilst the tapping is effected by means of a hole through the bottom near one of the sides. This, when closed, is stopped by means of an iron plug kept in its place by a weighted lever.

Concentration of the silver. — This process is founded on the circumstance first noticed in the year 1829, by the late H. L. Pattinson of Newcastle-on-Tyne, that

when lead containing silver is melted in a suitable vessel, afterwards slowly allowed to cool, and at the same time kept constantly stirred, at a certain temperature near the melting point of lead, metallic crystals begin to form. These as rapidly as they are produced sink to the bottom, and on being removed are found to contain much less silver than the lead originally operated on. The still fluid portion, from which the crystals have been removed, will at the same time be proportionally enriched.

1095 1096



This operation is conducted in a series of 8 or 10 cast iron pots, set in a row, with fireplaces beneath. These are each capable of containing about 6 tons of calcined lead; and on commencing an operation that quantity of metal, containing we will suppose 20 oz. of silver per ton, is introduced into a pot (say F, *fig.* 1095) about the centre of the series. This when melted, is carefully skimmed with a perforated ladle, and the fire immediately withdrawn. The cooling of the metal is also frequently hastened by throwing water upon its surface, and whilst cooling it is kept constantly agitated by means of a long iron stirrer or slice. Crystals soon begin to make their appearance, and these as they accumulate and fall to the bottom are removed by means of a large perforated ladle, in which they are well shaken, and afterwards carried over to the next pot to the left of the workman. This operation goes on continually until about 4 tons of crystals have been taken out of the pot F, and have been placed in pot E, at which time the pot F, may contain about 40 oz. of silver to the ton, whilst that in E, will only yield 10 oz. The rich lead in F, is then laded into the next pot G, to the right of the workman, and the operation repeated in F, on a fresh quantity of calcined lead.

In this way calcined lead is constantly introduced, and the resulting poor lead passes continually to the left of the workman, whilst the rich is passing towards his right. Each pot in succession, when filled with lead of its proper produce for silver, is in its turn crystallised, the poor lead passing to the left of the workman, and the enriched lead to his right. By this method of treatment it is evident that the crystals obtained from the pots to the left of the workman must gradually be deprived of their silver, whilst the rich lead passing to his right becomes continually richer. The final result is, that at one end of the series, the poor lead contains very little silver, whilst at the other an exceedingly rich alloy of lead and silver is obtained.

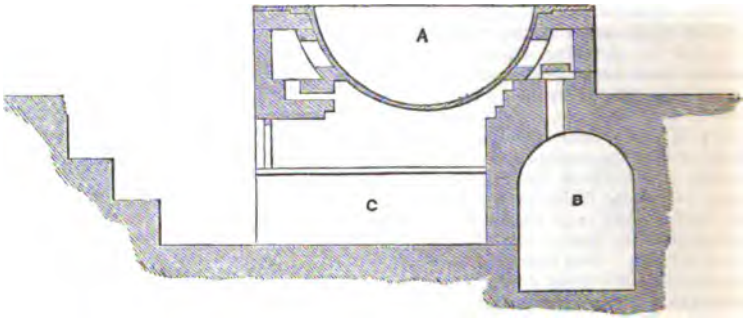
The poor lead obtained by this process should never contain more than 12 dwts. of silver per ton, whilst the rich lead is frequently concentrated to 500 oz. to the ton. This rich lead is subsequently cupelled in the refining furnace.

The ladle employed for the removal of the crystals, when manual labour is made use of, is about 16 inches in diameter, and 5 inches in depth, but when cranes are used much larger ladles are easily managed. A form of crane has been invented which effects considerable economy of labour in this operation. When, during the operation of crystallisation, the ladle becomes chilled, it is dipped into a small vessel containing lead of a higher temperature than that which is being worked, and known by the name of a temper-pot. The pot containing the rich lead is generally called the No. 1 pot; in some establishments, however, the last pot in which the poor lead is crystallised obtains this appellation.

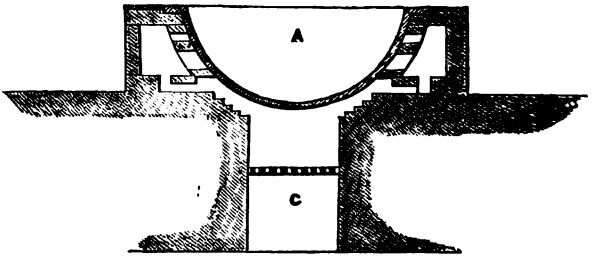
Figs. 1095 and 1096 represent a plan and elevation of a set of Pattinson's pots, arranged in the most approved way. A is the "market pot," from which the desilverised lead is laded out. B, C, D, E, F, G, H, and I, are the working pots, whilst A′, B′, C′, D′, E′, F′, G′, H′, and I, are their respective fireplaces. The "temper-pots" *a a a a*, are employed for heating the ladles when they have become too much reduced in temperature.

The *figs.* 1097 and 1098, are sections showing the manner of setting and the arrangement of the pots and flues. A, pot; B, main flue; C, ash pit.

1097



1098



The cost of crystallising one ton of calcined Spanish lead, in the establishment quoted when treating of calcination, is as follows:—

	s.	*d.*
Wages - - - - - - - - -	9	5·4
Coals, 4 cwts. - - - - - - - -	0	8·4
Repairs - - - - - - - - -	0	2·5
Total - - - - - - - -	10	4·3

The erection of nine six-ton pots requires 15,000 common bricks, 10,000 fire-bricks, 160 feet of quarles, 80 fire-clay blocks, and 5 tons of fire-clay.

In some establishments ten-ton pots are employed, and where cranes are made use of they are found to be advantageous.

Refining.—The extraction of the silver contained in the rich lead is conducted in a cupel forming the bottom of a reverberatory furnace called a refinery.

In this operation the litharge produced, instead of being absorbed by the substance of the cupel, is run off in a fluid state, by means of a depression called a gate.

The size of the fire-place varies with the other dimensions of the furnace, but is usually nearly square, and in an apparatus of ordinary size may be about 2 feet × 2 feet 6 inches. This is separated from the body of the furnace by a fire-bridge 18 inches in breadth, so that the flame and heated air pass directly over the surface of the cupel, and from thence escape by means of two separate apertures into the main flues of the establishment. The cupel or test consists of an oval iron ring, about 5 inches in depth, its greatest diameter being 4 feet, and its lesser nearly 3 feet. This frame, in order to better support the bottom of the cupel, is provided with cross-bars about 4½ inches wide, and one half-inch in thickness. In order to make a test, this frame is beaten full of finely-powdered bone-ash, slightly moistened with water, containing a small quantity of pearl-ash in solution, which has the property of giving consistency to the cupel when heated.

The centre of the test, after the ring has been well-filled with this mixture, and solidly beaten down, is scooped out with a small trowel, until the sides are left 2 inches in thickness at top, and three inches at the bottom, whilst the thickness of the sole itself is about 1 inch.

At the fore part or wide end of the test the thickness of the border is increased to six inches, and a hole is then cut through the bottom, which communicates with the openings or gates by which the fluid litharge makes its escape.

The test, when thus prepared, is placed in the refinery furnace, of which it forms the bottom, and is wedged to its proper height against an iron ring firmly built into the masonry. When this furnace is first lighted, it is necessary to apply the heat very gradually, since if the test were too strongly heated before it became perfectly dry, it would be liable to crack. As soon as the test has become thoroughly dry, it is heated to incipient redness, and is nearly filled with the rich lead to be operated on, which has been previously fused in an iron pot at the side of the furnace, and beneath which is a small grate where a fire is lighted.

The melted lead, when first introduced into the furnace, becomes covered with a greyish dross, but on further increasing the heat, the surface of the bath uncovers, and ordinary litharge begins to make its appearance.

The blast is now turned on, and forces the litharge from the back of the test up to the breast, where it passes over the gate, and falls through the aperture between the bone-ash and the ring into a small cast-iron pot running on wheels. The air, which is supplied by a small ventilator, not only sweeps the litharge from the surface of the lead towards the breast, but also supplies the oxygen necessary for its formation.

In proportion as the surface of the lead becomes depressed by its constant oxidation, and the continual removal of the resulting litharge, more metal is added from the melting pot, so as to raise it to its former level, and in this manner the operation is continued until the lead in the bottom of the test has become so enriched as to render it necessary that it should be tapped. The contents of the test are now so far reduced in volume that the whole of the silver contained in the rich lead operated on remains in combination with a few hundred weights only of metal, and this is removed by carefully drilling a hole in the bone-ash forming the bottom of the test. The reason for the removal of the rich lead, is to prevent too large an amount of silver from being carried off in the litharge, which is found to be the case when lead containing a very large amount of that metal is operated on.

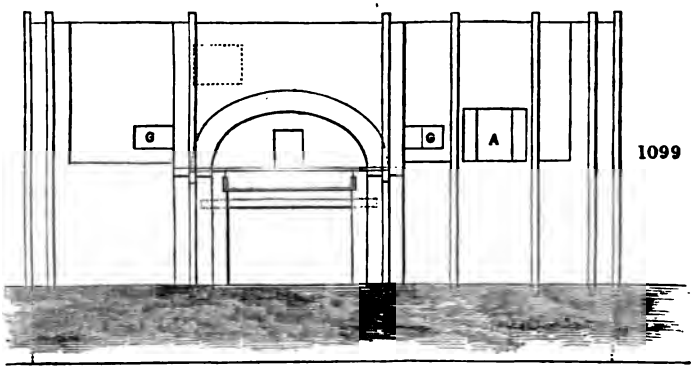
When the rich lead has been thus removed, the tapping hole is again closed by a pellet of bone-ash, and another charge immediately introduced.

As soon as the whole of the rich lead has been subjected to cupellation, and has become thus further enriched, the argentiferous alloy is itself similarly treated, either in a fresh test, or in that employed for the concentration of the rich lead. The brightening of pure silver at the moment of the separation of the last traces of lead, indicates the precise period at which the operation should be terminated, and the blast is then turned off, and the fire removed from the grate. The silver is now allowed to set, and as soon as it has become hardened, the wedges are removed from beneath the test, which is placed on the floor of the establishment. When cold, the silver plate is detached from the test, and any adhering particles of bone-ash removed by the aid of a wire brush.

A test furnace of ordinary dimensions requires for its construction about 2,000 common bricks, 2,000 fire-bricks, and 1½ tons of fire-clay. A furnace of this kind will work off 4 pigs of lead per hour, and consume 4 cwts. of coal per ton of rich lead operated on.

The cost of working a ton of rich lead in the neighbourhood of Newcastle, containing on an average 400 oz. of silver per ton, is as follows: —

	s.	d.
Refiner's wages	4	2·1
Coals, 4 cwt.	0	6·8
Engine wages	1	7·0
Coals, 5 cwt.	0	8·7
Pearl-ash	0	3·5
Bone-ash, 17·3 lbs.	3	1·0
Repairs	0	5·0
Total	10	10·1



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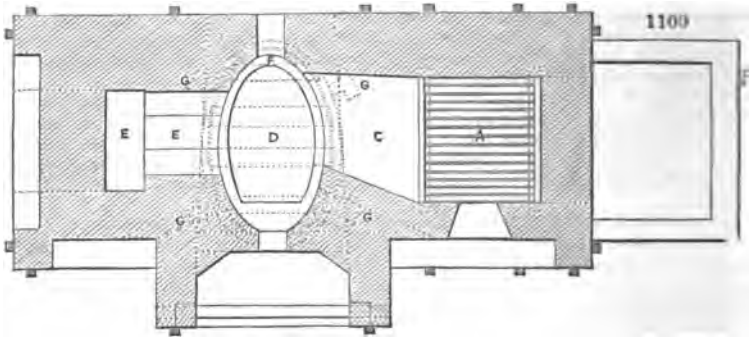
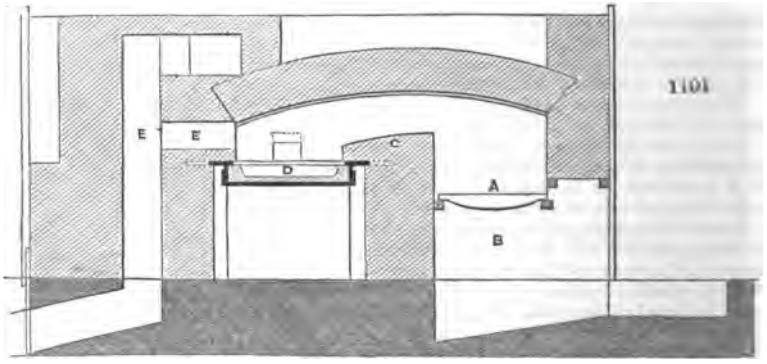


1100



1101

Figs. 1099, 1100, and 1101, represent an elevation, plan, and section of a refining furnace; A, fireplace; B, ash-pit; C, fire-bridge; D, test-ring, shown in its proper position; E, flues; F, point where blast enters; G, pig-holes.*

* Pig-holes are used for introducing the lead in cases in which it is not laded into the test in a fused state.

Reducing.—The reduction to the metallic state of the litharge from the refinery, the pot dross, and the mixed metallic oxides from the calcining furnace, is effected in a reverberatory apparatus, somewhat resembling a smelting furnace, except that its dimensions are smaller, and the sole, instead of being lowest immediately below the middle door, gradually slopes from the fire-bridge to near the flue, where there is a depression in which is inserted an iron gutter, which constantly remains open, and from which the reduced metal flows continuously into an iron pot placed by the side of the furnace for its reception, whence it is subsequently laded into moulds.

The litharge, or pot dross, is intimately mixed with a quantity of small coal, and is charged on that part of the hearth immediately before the fire-bridge. To prevent the fused oxide from attacking the bottom of the furnace, and also to provide a sort of hollow filter for the liquid metal, the sole is covered by a layer of bituminous coal.

The heat of the furnace quickly causes the ignition of this stratum, which is rapidly reduced to the state of a spongy cinder. The reducing gases present in the furnace, aided by the coal mixed with the charge itself, cause the reduction of the oxide, which, assuming the metallic form, flows through the interstices of the cinder, and ultimately finding its way into the depression at the extremity of the hearth, flows through the iron gutter into the external cast iron pot. The surface of the charge is frequently, during the process of elaboration, turned over with an iron rake, for the double purpose of exposing new surfaces to the action of the furnace, and also to allow the reduced lead to flow off more readily.

Fresh quantities of litharge or pot-dross, with small coals, are from time to time thrown in, in proportion as that already charged disappears, and at the end of the shift, which usually extends over 12 hours, the floor of cinder is broken up, and after being mixed with the residual matters in the furnace is withdrawn. A new floor of cinders is then introduced, and the operation commenced as before. A furnace of this kind, having a sole 8 feet in length and 7 feet in width, will afford, from litharge, about 5½ tons of lead in 24 hours.

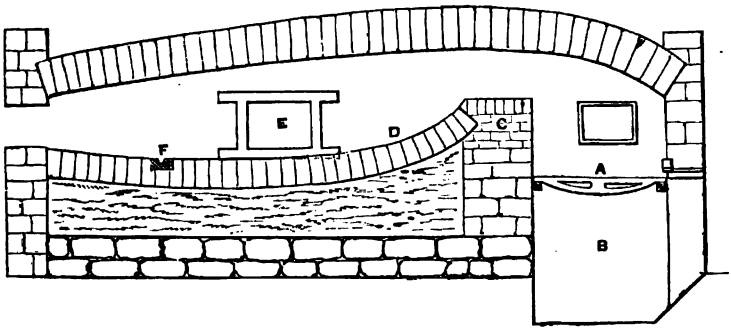
The dross from the calcining pan, when treated in a furnace of this description, should be previously reduced to a state of fine division, and intimately mixed up with small coal and a soda-ash. In many cases, however, the calcined dross is treated in the smelting furnace. The hard lead obtained from this substance is again taken to the calcining furnace, for the purpose of being softened.

The expense of reducing one ton of litharge may be estimated as follows:—

	s.	d.
Wages	2	6·0
Coals (3 cwts.)	0	5·2
Repairs	0	1·6
Total	3	0·8

In the establishment from which the foregoing data were obtained, the cost of slack, delivered at the works, was only 2*s.* 11*d.* per ton, which is cheaper than fuel can be obtained in the majority of the lead-mills of this country. In North Wales the cost of small coal is generally about 4*s.*, and at Bristol 5*s.* 6*d.* per ton.

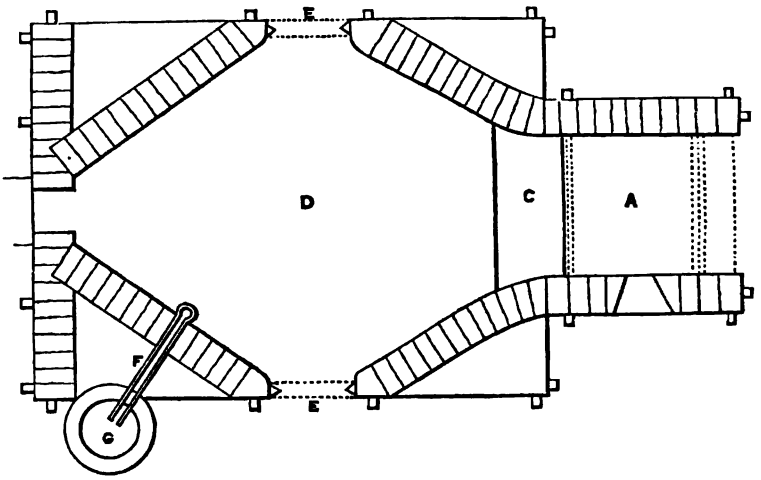
1102



Figs. 1102 and 1103 represent a vertical section and plan of a reducing furnace. A, fire-place; B, ash-pit; C, fire-bridge; D, hearth; E, working-door; F, iron spout for

conducting the reduced metal into the lead-pot a, which is kept heated by means of a fire beneath.

103



The total cost of elaborating one ton of hard lead, containing 30 oz. of silver per ton, in a locality in which fuel is obtained at the low price above quoted, is nearly as follows:—

	£	s.	d.
Calcining	0	2	4·4
Crystallising	0	9	6·5
Refining	0	0	9·2
Reducing—pot dross and litharge	0	1	0·8
Calcined dross	0	0	8·0
Slags	0	0	5·0
Bone-ash, &c.	0	0	7·0
Transport, &c.	0	1	1·0
Management, taxes, and interest of plant	0	5	10·0
Total	1	2	3·9

One hundred tons of hard lead treated gave:—

	Tons.
Soft lead	94·90
Black dross	3·72
Loss	1·38
Total	100·00

On comparing the expense of each operation, as given in the foregoing abstract, with the amounts stated as the cost of each separate process, they will be found to be widely different; but it must be remembered that the whole of the substances elaborated are far from being subjected to the various treatments described.

In order therefore to give an idea of the relative proportions which are passed through the several departments, I may state that in an establishment in which the ores are treated in the Castilian furnace the following were the results obtained:—

One-hundred parts of raw ore yield:—

Roasted ore	85
Hard lead	42
Soft „	36
Rich „	9
Dross and litharge re-treated	18½

The importance of this branch of our metallurgic industry will be gathered from the following tabular statements, chiefly derived from Mr. Hunt's valuable statistics:—

TABLE I.

Showing the Quantity of Lead Ore raised and smelted, average Metallic Yield of Ore per Cent., and Ratio of Lead produced in various Parts of the United Kingdom during Ten Years ending 1857.

Years.	England.		Wales.		Ireland.		Scotland.		Isle of Man.		Total.	
	Lead Ore.	Lead.	Lead Ore.	Lead.	Lead Ore.	Lead.	Lead Ore.	Lead.	Lead Ore.	Lead.	Lead Ore.	Lead.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
1848 - -	54,538	29,142	16,305	11,122	1,912	1,188	2,588	1,736	2,521	1,665	77,864	54,853
1849 - -	60,124	41,168	19,711	13,389	2,739	1,653	1,421	957	2,826	1,535	86,821	58,702
1850 - -	63,565	44,462	21,093	14,876	2,895	1,746	3,117	2,194	2,175	1,218	92,845	64,426
1851 - -	64,102	45,103	19,314	14,813	3,222	1,839	2,113	2,140	2,560	1,402	92,311	65,287
1852 - -	62,411	43,813	18,379	13,708	4,493	3,222	3,499	2,381	2,415	1,835	91,197	64,959
1853 - -	59,342	41,897	17,131	12,870	3,309	2,452	2,799	1,919	2,460	1,829	85,041	60,967
1854 - -	64,796	44,986	18,130	13,367	3,069	2,210	1,753	1,279	2,800	2,127	90,548	63,979
1855 - -	66,270	46,244	18,206	13,673	2,405	1,732	1,587	1,139	3,573	2,725	92,041	65,533
1856 - -	74,489	52,868	19,873	14,791	2,484	1,602	1,931	1,417	3,218	2,451	101,997	73,129
1857 - -	68,520	48,356	21,455	16,124	2,289	1,407	1,891	1,351	2,656	2,028	96,821	96,266
	638,157	448,039	189,597	138,733	28,827	,041	23,699	16,463	27,204	18,825	907,486	641,101
Average metallic yield per cent. of ore - -	70·2		73·1		66·0		69·4		69·1		70·6	
Ratio of lead produced -	69·9		21·7		3·0		2·5		2·1		100	

TABLE II.

Estimated Value of Lead and Silver consumed in Great Britain, 1857.

Lead and silver produced in the United Kingdom - - -		£1,670,353
Silver imported, 846,569 oz. - - - - - - - -		232,806
		1,903,159
Lead exported - - - - - -	22,397 tons.	
„ imported - - - - - -	12,768 „	
Balance of exports - - - -	9,629 - - -	211,838
Value consumed - - - - - -		£1,691,321

TABLE III.

Silver produced from Ores raised in Great Britain during Four Years ending 1857.

	1854.	1855.	1856.	1857.
	Oz.	Oz.	Oz.	Oz.
England - - - - -	419,824	439,983	481,909	417,343
Wales - - - - -	67,051	57,521	62,357	58,097
Ireland - - - - -	18,096	7,252	3,700	3,071
Scotland - - - - -	5,426	4,947	5,289	4,206
Isle of Man - - - - -	52,262	51,597	60,382	48,016
Total - - -	562,659	561,300	613,637	530,733
Value at 5*s.* 6*d.* per oz. -	£154,730	154,357	158,750	146,501

Market value of lead produced in the United Kingdom in 1857 -	£1,523,852
Ditto of silver - - - - - - - - - - - -	146,501
	1,670,353

It may be remarked that for the treatment of ores of good produce the reverberatory furnace and Scotch hearth are to be preferred, but for working minerals of a low percentage the blast furnace may generally be substituted with advantage. The slag hearth, from the amount of fuel consumed and loss experienced, is a somewhat expensive apparatus, and might in many cases be advantageously exchanged for the Castilian furnace.

It is well known that the losses which take place in this branch of metallurgy are,

from the volatility of the metal operated on, unusually large. In those establishments, however, in which due attention is paid to fluxes and a proper admixture of ores, as well as the condensation of the fumes, a great economy is effected.

In some instances flues of above five miles in length have been constructed, and the most satisfactory results obtained. The attention of lead smelters is being daily more directed to the prevention of the loss of metal by volatilisation, and those who have adopted the use of long flues have been, in all cases, quickly repaid for their outlay.

As an example of the great extent to which sublimation may take place on the scale employed in large smelting works, we may mention the lead works belonging to Mr. Beaumont in Northumberland. Formerly the fumes or smoke arising from various smelting operations escaped from ordinary chimneys or short galleries, and large quantities of lead were thus carried off in the state of vapour, and deposited on the surrounding land, where vegetation was destroyed, and the health of both men and other animals seriously affected. This led to various extensions of the horizontal or slightly inclined galleries now in use, and the quantity of lead extracted rapidly repaid the cost of construction. The latest addition of this kind was made at Allen Mill, by Mr. Sopwith, the manager, and completed a length of 8,789 yards (nearly five miles) of stone gallery from that mill alone. This gallery is 8 feet high and 6 wide, and is in two divisions widely separated. There are also upwards of 4 miles of gallery for the same purpose connected with other mills belonging to Mr. Beaumont in the same district, and in Durham; and we learn from Mr. Sopwith, that further extensions are contemplated. The value of the lead thus saved from being totally dissipated and dispersed, and obtained from what in common parlance might be called chimney sweepings, considerably exceeds 10,000*l.* sterling annually, and forms a striking illustration of the importance of economising our waste products.

In lieu of long and extensive flues, condensers of various descriptions have from time to time been introduced, but in most instances the former have been found to be more efficient.

When, however, water can be procured for the purpose of cooling the condensers excellent results are generally obtained.—J. A. P.

See LITHARGE, MINIUM, or *Red Lead*, SOLDER, SUGAR or *Acetate* OF LEAD, TYPE METAL, and WHITE LEAD.

LEAD ORES, ASSAY OF. The ores of lead may be divided into two classes.

The *first class* comprehends all the ores of lead which contain neither sulphur nor arsenic, or in which they are present in small proportion only.

The *second class* comprises galena, together with all lead ores containing sulphur, arsenic, or their acids.

From the facility with which this metal is volatilised when strongly heated, it is necessary to conduct the assay of its ores at a moderate temperature.

A common wind furnace is best adapted for making lead assays. For this purpose the cavity for the reception of fuel should be 9 inches square, and the height of the fine-way from the fire-bars about 14 inches. For ordinary ores a furnace 8 inches square and 12 inches deep will be found sufficient; but as it is easy to regulate, by a damper, the heat of the larger apparatus, it is often found advantageous to be able to produce a high temperature.

A furnace of this kind should be connected with a chimney of at least twenty feet in height, and be supplied with good coke, broken into pieces of the size of eggs.

ORES OF THE FIRST CLASS. — The assay of ores of this class is a simple operation, care being only required that a sufficient amount of carbonaceous matter be added to effect the reduction of the metal, whilst such fluxes are supplied as will afford a readily-fusible slag.

When the sample has been properly reduced in size, 400 grains are weighed out and well mixed with 600 grains of carbonate of soda, and from 40 to 60 grains of finely-powdered charcoal, according to the richness of the mineral operated on.

This is introduced into an earthen crucible, of such a size as not to be more than one-half filled by the mixture, and on the top is placed a thin layer of common salt. The crucible is then placed in the furnace and gently heated, care being taken to so moderate the temperature, that the mixture of ore and flux, which soon begins to soften and enter into ebullition, may not swell up and flow over. If the action in the crucible becomes too strong, it must be checked by removal from the fire, or by a due regulation of the heat by means of a damper. When the action has subsided, the temperature is again raised for a few minutes, and the assay completed. During the process of reduction, the heat should not exceed dull redness; but in order to complete the operation, and render the slag sufficiently liquid, the temperature should be raised to bright redness.

When the contents have been reduced to a state of tranquil fusion, the crucible must be removed from the fire and the assay either rapidly poured, or, after being tapped against some hard body to collect the lead in a single globule, be set to cool.

When the operation has been successfully conducted, the cooled slag will present a smooth concave surface, with a vitreous lustre. When cold the crucible may be broken, and the button extracted. To remove from it the particles of adhering slag, it is hammered on an anvil, and afterwards rubbed with a hard brush.

Instead of employing carbonate of soda and powdered charcoal, the ore may be fused with 1½ times its weight of black flux, and the mixture covered by a thin layer of borax.

Good results are also obtained by mixing together 400 grains of ore with an equal weight of carbonate of soda and half that quantity of crude tartar. These ingredients, after being well incorporated, are placed in a crucible, and slightly covered by a layer of borax.

Each of the foregoing methods yields good results, and affords slags retaining but a small proportion of lead.

ORES OF THE SECOND CLASS. — This class comprehends galena, which is the most common and abundant ore of lead, and also comprises sundry metallurgic products, as well as the sulphates, phosphates, and arseniates of lead.

Galena. — The assay of this ore is variously conducted; but one of the following methods is usually employed for commercial purposes.

Fusion with an alkaline flux. — This operation is conducted in an earthen crucible which is to be kept uncovered until its contents are reduced to a state of perfect fusion.

The powdered ore, after being mixed with three times its weight of carbonate of soda and 10 per cent. of finely pulverised charcoal, is slowly heated in an ordinary assay furnace until the mixture has become perfectly liquid, when the pot is removed from the fire, and, after having been gently tapped, to collect any globules of metal held in suspension in the slag, is put aside to cool. When sufficiently cold, the crucible is broken, and a button of metallic lead will be found at the bottom: this must be cleansed and weighed.

In place of carbonate of soda, pearlash may be employed, or the fusion may be effected with black flux alone. When the last-named substance is used a somewhat longer time is necessary for the complete fusion of the assay. Each 100 parts of pure galena will by this method afford from 74 to 76 parts of lead.

Some of the old assayers were in the habit of first driving off the sulphur by roasting, and afterwards reducing the resulting oxide with about its own weight of black flux.

This method, from the great fusibility of the compounds of lead, requires very careful management, and at best the results obtained are unsatisfactory. Pure galena by this method can rarely be made to yield more than 70 per cent. of lead.

Fusion with metallic iron.—Mix the ore to be assayed with twice its weight of carbonate of soda, and, after having placed it in an earthen crucible, of which it should occupy about one half the capacity, insert with their heads downward three or four tenpenny nails, and press the mixture firmly around them. On the top place a thin layer of borax, which should be again covered with a little common salt. The whole is now introduced into the furnace and gradually heated to redness; at the expiration of ten minutes the temperature is increased to bright redness, when the fluxes will be fused and present a perfectly smooth surface. When this has taken place, the pot is removed from the fire, and the nails are separately withdrawn by the use of a small pair of tongs, care being taken to well cleanse each in the fluid slag until free from adhering lead. When the nails have been thus removed, the pot is gently shaken, to collect the metal into one button, and laid aside to cool; after which it may be broken, and the button removed.

Instead of first allowing the slags to cool and then breaking the crucible, the assay may, if preferred, after the withdrawal of the nails, be poured into a mould.

Assay in an iron pot.—Instead of adding metallic iron to the mixture of ore and flux, it is generally better that the pot itself should be made of that metal.

For this purpose, a piece of half-inch plate-iron is turned up in the form of a crucible and carefully welded at the edges. The bottom is closed by a thick iron rivet, which is securely welded to the sides, and the whole then finished on a properly formed mandril. To make an assay in a crucible of this kind, it is first heated to dull redness, and, when sufficiently hot, the powdered ore, intimately mixed with its own weight of carbonate of soda, half its weight of pearlash, and a quarter of its weight of crude tartar, is introduced by means of a copper scoop. On the top of the whole is placed a thin layer of borax, whilst the crucible, which, for the ready introduction of the mixture, has been removed from the fire, is at once replaced. The heat is now raised to redness, the contents gradually becoming liquid and giving off large quantities of gas. At the expiration of from eight to ten minutes the mixture will be in a state of complete fusion; the pot is now partially removed from the fire, and its contents briskly stirred with a small iron rod. Any matter adhering to its sides is also scraped to the bottom of the pot, which after being again placed in a hot part of the furnace is heated during three or four minutes to bright redness.

The crucible is then seized by a strong pair of bent tongs, on that part of the edge which is opposite the lip, and its contents rapidly poured into a cast iron mould. The sides of the pot are now carefully scraped down with a chisel-edge bar of iron, and the adhering particles of metallic lead added to the portion first obtained. When sufficiently cooled the contents of the mould are easily removed, and the button of lead cleaned and weighed. By this process pure galena yields 84 per cent. of metallic lead, free from any injurious amount of iron, and perfectly ductile and malleable.

This method of assaying is that adopted in almost all lead-smelting establishments, and has the advantage of affording good results with all the ores belonging to the second class.

Assay in the iron dish.—In some of the mining districts of Wales, the assay of lead ore is conducted in a manner somewhat different to that just described. Instead of fusing the ore in an iron crucible with carbonate of soda, pearlash, tartar and borax, the fusion is effected in a flat iron dish, without the admixture of any sort of flux.—J. A. P.

Number of Lead Mines, Quantities, and total Value of Ore raised and of metallic Lead produced therefrom, in each County in England, Wales, Scotland, and Ireland, in each of the Years 1856, 1857, *and* 1858.

	Number of Mines.			Lead Ore.			Metallic Lead from Ore raised in each County.		
	1856.	1857.	1858.	1856.	1857.	1858.	1856.	1857.	1858.
ENGLAND.				Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
Cornwall	42	42	35	9,973	9,560	9,710	6,597	6,036	5,436
Devonshire	14	15	12	3,138	2,490	2,779	2,000	1,536	1,655
Cumberland	73	81	76	7,311	6,450	7,235	5,321	4,711	5,207
Durham and Northumberland	34	35	36	24,125	21,580	19,999	17,674	17,073	16,776
Westmoreland	11	11	6	2,923	2,798	2,190	2,179	2,103	1,673
Derbyshire	-	-	-	9,524	9,233	10,466	6,961	6,061	6,277
Shropshire	9	14	14	4,407	3,350	3,994	3,228	2,561	2,993
Yorkshire	14	14	14	12,174	12,406	11,480	8,986	7,876	7,605
Somersetshire	1	5	5	750	485	1,000	500	351	485
Total	198	218	198	74,325	68,452	68,863	52,746	48,308	48,100
WALES.									
Cardiganshire	47	51	30	8,560	7,573	7,086	6,191	5,510	5,440
Carmarthenshire	3	2	3	1,280	1,081	1,328	932	776	934
Denbighshire	2	7	10	3,103	4,181	4,749	2,367	3,241	3,728
Flintshire	48	48	34	4,607	3,006	3,696	3,513	2,281	2,839
Montgomeryshire	12	14	14	1,723	2,389	1,975	1,349	1,839	1,495
Merionethshire	7	8	5	349	332	326	266	250	244
Radnorshire	2	2	2	12	108	102	8	81	76
Caernarvonshire	3	10	9	237	442	289	163	321	202
Total	124	142	107	19,871	19,112	19,675	14,789	14,299	14,661
ISLE OF MAN	4	5	4	3,217	2,656	- -	2,450	2,028	
SCOTLAND.									
Argyleshire	2	1	1	148	51	44	109	39	34
Kirkcudbrightshire	4	4	6	320	239	235	252	172	166
Lanarkshire	1	2	2	525	689	1,087	355	456	717
Dumfriesshire	1	1	1	808	850	870	606	640	630
Perthshire	1	1	1	130	61	54	94	42	37
Total	9	9	11	1,931	1,890	2,290	1,416	1,350	1,585
IRELAND.									
Armagh	-	1	1	- -	30	69	- -	21	42
Clare	-	-	4	- -	- -	40	- -	- -	25
Down	1	1	1	602	453	323	430	363	242
Wicklow	2	2	2	1,520	1,653	2,054	933	915	1,317
Galway	-	-	1						
Donegal	-	-	1						
Kerry	-	-	-						
Monaghan	-	-	1	- -	- -	2	- -	- -	1
Cork	1	-	1	50	- -	- -	32		
Waterford	3	3	3	311	162	84	206	107	54
Total	7	7	15	2,483	2,298	2,603	1,601	1,406	1,704
Sundries under 10 tons	-	-	-	170	67	93	127	48	70
				101,997	94,475	95,938	73,129	67,439	67,979
				Estimated Value.					
Total	342	381	335	£	£	£	£	£	£
				1,431,509	1,393,506	1,466,646	1,755,096	1,483,658	1,489,008

LEAD-SHOT. (*Plomb de Chasse*, Fr.; *Schrot, Flintenschrot*, Germ.) The origin of most of the imperfections in the manufacture of lead-shot is the too rapid cooling of the spherules by their being dropped too hot into the water, whereby their surfaces form a solid crust, while their interior remains fluid, and in its subsequent concretions, shrinks, so as to produce the irregularities of the shot.

The patent shot towers originally constructed in England obviate this evil by exposing the fused spherules after they pass through the cullender, to a large body of air during their descent into the water tub placed on the ground. The highest erection of this kind is probably at Villach in Carinthia, being 240 Vienna, or 249 English feet high.

The quantity of arsenic added to the mass of melted lead varies according to the quality of this metal; the harder and less ductile the lead is, the more arsenic must be added. About 3 pounds of either white arsenic or orpiment is enough for one thousand parts of soft lead, and about 8 for the coarser kinds. The latter are employed preferably for shot, as they are cheaper and answer sufficiently well. The arsenical alloy is made either by introducing some of this substance at each melting; or by making a quantity of the compound considerably stronger at once, and adding a certain portion of this to each charge of lead. If the particles of the shot appear lens-shaped, it is a proof that the proportion of arsenic has been too great; but if they are flattened upon one side, if they are hollowed in their middle, called *cupping* by the workmen, or drag with a tail behind them, the proportion of arsenic is too small.

The following is the process prescribed by the patentees, Ackerman and Martin. Melt a ton of soft lead, and sprinkle round its sides in the iron pot about two shovelfuls of wood ashes, taking care to leave the centre clear; then put into the middle about 40 pounds of arsenic to form a rich alloy with the lead. Cover the pot with an iron lid, and lute the joints quickly with loam or mortar to confine the arsenical vapours, keeping up a moderate fire to maintain the mixture fluid for three or four hours; after which skim carefully, and run the alloy into moulds to form ingots or pigs. The composition thus made is to be put in the proportion of one pig or ingot into 1000 pounds of melted ordinary lead. When the whole is well combined, take a perforated skimmer, and let a few drops of it fall from some height into a tub of water. If they do not appear globular, some more arsenical alloy must be added.

Lead which contains a good deal of pewter or tin must be rejected, because it tends to produce elongated drops or tails.

From two to three tons are usually melted at once in the large establishments. The surface of the lead gets covered with a crust of oxide of a white spongy nature, sometimes called *cream* by the workmen, which is of use to coat over the bottom of the cullender, because without such a bed the heavy melted lead would run too rapidly through the holes for the granulating process, and would form oblong spheroids. The mounting of this filter, or lining of the cullender, is reckoned to be a nice operation by the workmen, and is regarded usually as a valuable secret.

The cullenders are hollow hemispheres of sheet iron, about 10 inches in diameter, perforated with holes, which should be perfectly round and free from burs. These must be of an uniform size in each cullender; but of course a series of different cullenders with sorted holes for every different size of lead-shot must be prepared. The holes have nearly the following diameters for the annexed numbers of shot.

No. 0.	- - - - - -	$\frac{1}{50}$ of an inch.
1.	- - - - - -	$\frac{1}{58}$ "
2.	- - - - - -	$\frac{1}{66}$ "
3.	- - - - - -	$\frac{1}{72}$ "
4.	- - - - - -	$\frac{1}{80}$ "

From No. 5. to No. 9. the diameter decreases by regular gradations, the latter being only $\frac{1}{100}$ of an inch.

The operation is always carried on with three cullenders at a time; which are supported upon projecting grates of a kind of chafing dish made of sheet iron somewhat like a triangle. This chafing dish should be placed immediately above the fall; while at its bottom there must be a tub half filled with water for receiving the granulated lead. The cullenders are not in contact, but must be parted by burning charcoal in order to keep the lead constantly at the proper temperature, and to prevent its solidifying in the filter. The temperature of the lead bath should vary with the size of the shot; for the largest, it should be such that a bit of straw plunged into it will be scarcely browned, but for all it should be nicely regulated. The height from which the particles should be let fall varies likewise with the size of the shot; as the congelation is the more rapid, the smaller they are. With a fall of 33 yards or 100 feet, from No. 4 to No. 9 may be made: but for larger sizes, 150 feet of height will be required.

Everything being arranged as above described, the workman puts the filter-stuff into the cullender, pressing it well against the sides. He next pours lead into it with an iron ladle, but not in too great quantity at a time, lest it should run through too fast. The shot thereby formed and found in the tub are not all equal.

The centre of the cullender being less hot affords larger shot than the sides, which are constantly surrounded with burning charcoal. Occasionally, also, the three cullenders employed together may have holes of different sizes, in which case the tub may contain shot of very various magnitudes. These are separated from each other by square sieves of different fineness, 10 inches broad and 16 inches long, their bottoms being of sheet iron pierced with holes of the same diameters as those of the cullenders. These sieves are suspended by means of two bands above boxes for receiving the shot; one sieve being usually set above another in consecutive numbers, for instance, 1 and 2. The shot being put into the upper sieve, No. 0 will remain in it; No. 1 will remain in the lower sieve, and No. 2 will, with all the others, pass through it into the chest below. It is obvious that by substituting sieves of successive fineness, shot of any dimensions may be sorted.

In the preceding process the shot has been sorted to size; it must next be sorted to form, soas to separate all the spheroids which are not truly round, or are defective in any respect. For this purpose a board is made use of about 27 inches long and 16 broad, furnished partially with upright ledges; upon this tray a handful or two of the shot to be sorted being laid, it is inclined very slightly, and gently shaken in the horizontal direction, when the globular particles run down by one edge, into a chest set to receive them, while those of irregular forms remain on the sides of the tray, and are reserved to be re-melted.

After being sorted in this way, the shot requires still to be smoothed and polished bright. This object is effected by putting it into a small octagonal cask, through a door in its side, turning upon a horizontal iron axis, with rests in plummer boxes at its ends, and is made to revolve by any mechanical power. A certain quantity of plumbago or black lead is put in along with the shot.

LEAD, CARBONATE OF. See WHITE LEAD.

LEAD, NITRATE OF (*Nitrate de plomb*, Fr.; *Salpetersaures bleioxyd*, Germ.), is made by saturating somewhat dilute nitric acid with oxide of lead (litharge), evaporating the neutral solution till a pellicle appears, and then exposing it in a hot chamber till it be converted into crystals, which are sometimes transparent, but generally opaque white octahedrons. Their spec. grav. is 4·068; they have a cooling, sweetish, pungent taste. They dissolve in 7 parts of cold, and in much less boiling water; they fuse at a moderate elevation of temperature, emit oxygen gas, and pass into oxide of lead. Their constituents are 67·3 oxide and 32·7 acid. Nitrate of lead is much employed in the chrome yellow style of CALICO-PRINTING; which see.

There are three other compounds of nitric acid and lead oxide; viz. the bi-basic, the tri-basic, and the se-basic; which contain respectively 2, 3, and 6 atoms of base to 1 of acid.

LEAD, OXICHLORIDE OF. A white pigment patented by Mr. Hugh Lee Pattinson of Newcastle, which he prepares by precipitating a solution of chloride of lead in hot water with pure lime water, in equal measures; the mixture being made with agitation. As the operation of mixing the lime water, and the solution of chloride of lead, requires to be performed in an instantaneous manner, the patentee prefers to employ for this purpose two tumbling boxes of about 16 feet cubic capacity, which are charged with the two liquids, and simultaneously upset into a cistern in which oxichloride of lead is instantaneously formed, and from which the mixture flows into other cisterns, where the oxichloride subsides. This white pigment consists of one atom of chloride of lead and one atom oxide of lead, with or without an atom of water.

LEAD, SALTS OF. The salts of lead, beyond those already named, which enter into any of our manufactures, are few and unimportant. *Ure's Dictionary of Chemistry* should be consulted for them.

LEATHER. (*Cuir*, Fr.; *Leder*, Germ.; *Leer*, Dutch; *Læder*, Danish; *Läder*, Swedish; *Cuojo*, Italian; *Cuero*, Spanish; *Kusha*, Russian.) This substance consists of the skins of animals chemically changed by the process called *tanning*. Throughout the civilised world, and from the most ancient times this substance has been employed by man for a variety of purposes. Barbarous and savage tribes use the skins of beasts as *skins*; civilised man renders the same substance unalterable by the external agents which tend to decompose it in its natural state, and by a variety of peculiar manipulations prepares it for almost innumerable applications.

Although the preparation of this valuable substance in a rude manner has been known from the most ancient times, it was not until the end of the last, and the beginning of the present century (1800) that it began to be manufactured upon right principles, in consequence of the researches of Macbride, Deyeux, Seguin, and Davy.

Skins may be converted into leather either with or without their hair; generally, however, the hair is removed.

The most important and costly kinds are comprised under sole leather and upper leather, to which may be added harness leather, belts used in machinery, leather hose, &c., but as far as the tanner is concerned, these are comprehended almost entirely in the kinds known as upper leather.

The active principle by which the skins of animals are prevented from putrefying, and at the same time, under some modes of preparation, rendered comparatively impervious to water, is called tannin, or tannic acid, a property found in the bark of the various species of Quercus, but especially plentiful in the gall-nut. When obtained pure, as it may easily be from the gall-nut, by chemical means, tannic acid appears as a slightly yellowish, almost a colourless mass, readily soluble in water; it precipitates gelatin from solution, forming what has been called *tannogelatin*. Tannic acid also precipitates albumen and starch. There can be little difficulty, after knowing the chemical combination just alluded to, in understanding the peculiar and striking change produced on animal substance in the formation of leather. The hide or skin consists principally of gelatin, for which the vegetable astringent tannin has an affinity, and the chemical union of these substances in the process of tanning produces the useful article of which we are treating.

Before entering upon the various processes by which the changes are effected on the animal fibre, it may not be uninteresting to speak of some of the principal astringents used for the purpose of producing these effects.

Bark obtained from the oak-tree is the most valuable and the most extensively used ingredient in tanning, and for a long time no other substance was used in England for the purpose. In consequence of the demand having become very much greater than the supply, and the consequent increase in the price of the article, it became necessary to investigate its properties, in order, if possible, to furnish the required quantity of tanning matter from other sources. Among other substitutes which were tried with some success in other countries may be mentioned *heath*, *myrtle leaves*, *wild laurel leaves*, *birch-tree bark*, and (according to the *Penny Cyclopædia*) in 1765 oak sawdust was applied in England, and has since been used in Germany for this purpose.

Investigation proved that the tanning power of oak bark consisted in a peculiar astringent property, to which the name of *tannin* has been given, and this discovery suggested that other bodies possessing this property would be suitable substitutes.

According to Sir H. Davy the following proportions of tannin in the different substances mentioned will be found: — "8½ lbs. of oak bark are equal to 2¼ lbs. of galls, to 3 lbs. of sumach, to 7½ lbs. of bark of Leicester willow, to 11 lbs. of the bark of the Spanish chestnut, to 18 lbs. of elm bark, and to 21 lbs. of common willow bark." — *Penny Cyclopædia.*

Oak bark contains more tannin when cut in spring by four and a half times, than when cut in winter; it is also more plentiful in young trees than in old ones. About 40,000 tons of oak bark are said to be imported into this country annually, from the Netherlands, Germany, and ports in the Mediterranean. The quantity of English oak bark used we have no means of ascertaining. It is prepared for use by grinding it to a coarse powder between cast iron cylinders, and laid into the tanpits alternately with the skins to be tanned. Sometimes, however, as will be hereafter noticed, an infusion of the bark in water is employed with better effect.

Mimosa.—The bark and pods of several kinds of Prosopis, the astringent properties of which have rendered them valuable in tanning, are known in commerce by this

1104

1105

name. The Mimosæ are a division of the leguminous order of plants, which consists of a large number of species, the Acacia being the principal. The sensitive plants

belong to this division. The proposis is found in India and South America; the genus consists both of shrubs and trees.

Valonia.—The oak which produces this acorn is the *Quercus Ægilops*, or great prickly cupped oak (*figs.* 1104, 1105). These are exported from the Morea and Levant; the husk contains abundance of tannin.

Catechu, or *Terra Japonica*, is the inspissated extract of the *Acacia catechu*. At the time the sap is most perfectly formed the bark of the plant is taken off, the tree is then felled, and the outer part removed; the heart of the tree, which is brown, is cut into pieces and boiled in water; when sufficiently boiled it is placed in the sun, and, subject to various manipulations, gradually dried. It is cut into square pieces, and much resembles a mass of earth in appearance; indeed it was once considered to be such, hence the name *Terra Japonica*.

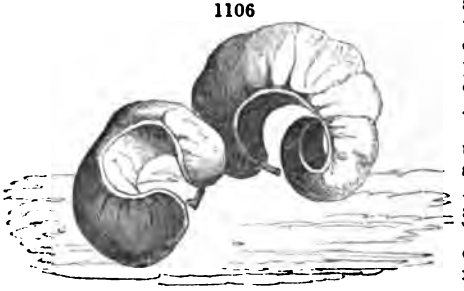
We give Sir H. Davy's analysis; the first numbers represent Bombay, the second Bengal catechu:—

Tannin	109	97
Extractive	68	73
Mucilage	13	16
Impurities	10	14

This astringent is also obtained from the *Uncaria Gambir*.

Dividivi is a leguminous plant of the genus Cæsalpinia, *C. coriaria*. The legumes of this species are extremely astringent, and contain a very large quantity of tannic and gallic acid; they grow in a very peculiar manner, and become curiously curled as they arrive to perfection. The plant is a native of America, between the tropics. *Fig.* 1106.

1106



Sumach is a plant belonging to the genus Rhus; several of the species have astringent properties; *Rhus cotinus* and *Rhus coriaria* are much used in tanning; the bark of the latter is said to be the only ingredient used in Turkey for the purpose of converting gelatin into leather. That used in this country is ground to a fine powder, and is extensively applied to the production of bright leather, both by tanners and curriers.

Many other vegetable products have been from time to time proposed, and to some extent adopted for the same end, but they need not be enumerated.

The process first attended to by the tanner is simply to soak the skin or hide in water; those from the home market may be said to be washed merely, as they remain in water only a few hours; while hides imported from foreign countries, and which have been preserved by salting or drying, *and especially the latter*, require soaking for a longer period, in order to render them supple, and beating or rubbing materially assists in bringing them to the required condition.

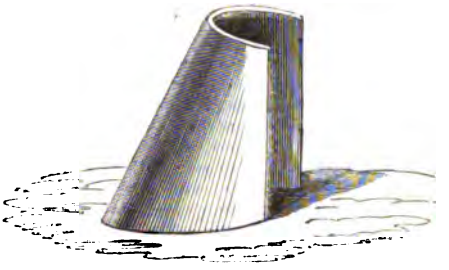
After removing the horns, the softened or recent hides are laid in a heap for a short time, after which they are suspended on poles in a close room called a smoke-house, heated somewhat above the common temperature by a smouldering fire. In these circumstances, a slight putrefaction supervenes, which loosens the epidermis, and renders the hair easily detachable. This method for removing the hair is by no means general in this country. The plan adopted is to place the hides in a large vat or pit, containing milk of lime, in which they must be moved frequently, to allow the lime to act equally on every part. When the menstruum has taken proper effect, the hair is easily removed, and for this purpose the hide is spread out, and a blunt tool is worked over the surface. The hair being removed, the hide is washed in water to cleanse it from the lime, which must be most thoroughly effected.

The heaviest hides are for the most part tanned for sole leather, and as the thinner parts are cut off previous to their being prepared for sale, they have received the name of *butts* or *backs*: the various processes through which these pass will be first described.

After removing the hair and washing, the hides are placed on a convex beam (*fig.* 1107), and worked with a concave tool with two handles (*fig.* 1108), in order to remove any flesh or fatty matter which may adhere to them; this being done they are worked on the same beam, on the grain side, to drive out the grease and remove any remaining hair. The *fleshings* are pressed into cakes and sold for making glue, as are all such portions of the hide or skin as cannot be conveniently worked. The hair is sold to plasterers, to be used in their mortar; and the tails, also for the hair, to sofa-makers and others requiring such materials.

Such hides as are designed for machinery purposes are next immersed in a pit containing water impregnated with sulphuric acid, the acid varying from $\frac{1}{300}$ to $\frac{1}{1000}$ of the mixture. This process is called *raising*, because it distends the pores, and makes the fibres swell, so as to become more susceptible of the action of tanning infusions. Forty-eight hours in general suffice for this operation, but more time may be safely taken. From the term *raising* it will be concluded that the substance of the hide is increased, and this is the fact; but as the gelatine is not increased it is said that the shoemaker's hammer would condense the leather so much that it would lose any supposed advantage arising out of this increase in thickness. There is, however, a method of augmenting the substance of sole leather called *puffing*, which, when once communicated, appears to exist permanently; the process is known to a small extent only, and the material is said to be considerably injured by this mode of preparation.

1107



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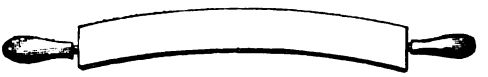
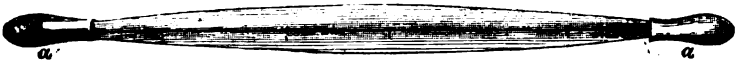


When the hides are sufficiently *raised*, they are transferred to a pit supplied with a weak infusion of bark; here they are *handled*, at first several times a day, that is, they are drawn out of the pits, or moved up and down in the *liquor*, to prevent the grain from being drawn into wrinkles. As the *ooze*, or tanning infusion, takes effect, they are put into pits containing stronger liquors, and after a month or six weeks they are placed in a pit, in which they are stratified with oak bark, ground by a proper mill into a coarse powder. The pit is then filled with an infusion of bark. In a month or five weeks the tanning and extractive matter of the bark will have intimately combined with the animal fibre; the pit, exhausted of its virtue, must be renewed by taking out the spent bark and repeating the dose as in the first instance. The hides, which were placed at the top of the pit at first, are now put into the bottom, to equalise the action. In about three months this also is spent, and the process being repeated two or three times more the operation is complete. The hides are now removed from the pit, and hung up in a shed. In the progress of drying they are compressed with a steel tool, and afterwards they are subjected to the action of a brass roller. The steel tool is called a *pin*; it is of a triangular shape (*fig.* 1109), with the sides scooped out (*fig.* 1110), presenting three blunt edges. The butt is thrown across a pole,

1109



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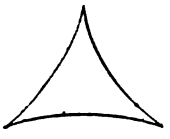
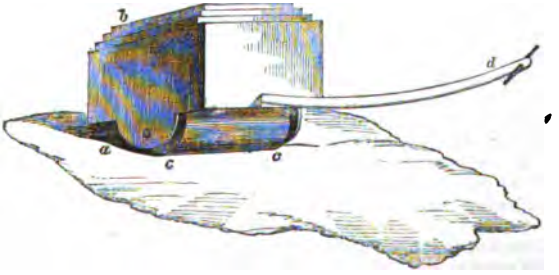




and the workman taking the pin by the handles *a*, *a* (*fig.* 1100), presses it forcibly over the grain side of the leather; after carefully compressing every part in this way, the *butt* is laid upon a flat bed of solid wood-work, prepared for the purpose, and the brass roller is worked backward and forward until every portion is sufficiently compressed (*fig.* 1111). The roller *a* is a cylinder varying from 9 to 12 inches in length, and from

7 to 10 inches in diameter; *b* is an open box over the roller, into which weights are placed to make the necessary pressure, ten or twelve cwt. being frequently used for the purpose; *c*, *c*, forms a fulcrum for lifting the roller from the bed to the leather; *d* is the handle by which the machine is worked. When the compression is completed, the only thing remaining to be done is properly to dry the leather, and then it is fit for the market.

Some manufacturers place on the bottom of the tan pit five or six inches of spent bark, and two or three inches of fresh bark over it, then a hide, and so alternately bark and a hide, until the pit is nearly full, reserving a small space at the top for a thicker layer of bark, over which weighted boards are laid, to condense the whole down into the tanning infusion.

The operation of tanning sole leather by the above method occupies a year or more, the time depending on the nature and stoutness of the hide.

A perfect leather is recognised by its section, which should have a glistening marbled appearance, without any white streak in the middle.

Crop hides are manufactured very much like butts, that is to say, they are placed in milk of lime until the hair is sufficiently loosened, equality of action being secured by occasionally moving them in the menstruum; they are then cleared of the hair and other impurities by the *fleshing knife*, worked on the convex beam already described, they are then freed from lime by thorough washing. The next process is to plunge them into a weak ooze, from which they are transferred to other pits with stronger ooze; all the while they are frequently *handled*, that is, moved up and down in the infusion. After a month or six weeks they are subjected to a mixture of ground oak bark and stronger ooze in other pits, to a series of which they are progressively subjected during two or three months.

The hides are next put into large vats called *layers*, in which they are smoothly stratified, with more bark and a stronger infusion. After about six weeks they are taken out of these vats, and subjected to a new charge of this material, and allowed to lay some two months; this process is repeated once or twice more till the hides are thoroughly tanned. They are then slowly dried in the shed, and folded for market. Although in general the stoutest and most compact hides are used as sole leather (notwithstanding that they have not been condensed by the tanner, as in the case of *butts*), yet many are appropriated to other purposes by the currier, and the lighter cow hides are manufactured for the upper leather of stout shoes, water boots, &c.

The process of tanning *skins* (as calves, seals, &c.) next claims attention. These are placed in the lime pits until the hair can be easily removed, a process which requires about ten or twelve days; this being accomplished, they are next washed in water so as completely to remove the lime, as far as washing can secure its removal, and then immersed in a lixivium of pigeon's dung, dog's dung, or matters of a like nature; in this state they remain about ten or twelve days, the state of the atmosphere rendering the process quicker at one time than another; here also they are frequently handled, and *worked* on both sides on the convex beam. The working, joined to the action of the peculiar lixivium, serves to separate the remaining lime, oil, and glutinous matter, and at the same time to render the skin pliant, soft, and ready to imbibe the tanning principle. It is important that great attention should be paid to the process just described, as too short a period would produce a hard and crisp leather, while a few hours more than is necessary makes the article coarse and spongy, both of which conditions should be very carefully guarded against.

The skins are next removed to a pit containing a weak solution of bark, in which they undergo nearly the same treatment as *crop hides*, but they are not commonly stratified in the layers. About three months is usually occupied in tanning calfskins, but of course the stouter the skin the more will be the time required. When dried they are disposed of to the currier, who dresses them for the upper leathers of boots, shoes, and a variety of other purposes. It is not unusual for the lighter *cow hides* to be treated like calfskins.

Horse hides are also treated like calfskins; but as the horse hide, with the exception of the part on and near the animal's rump, produces a thin leather, it is usual, before subjecting the hide to the action of the bark, to cut out what is called the *butt*, which is tanned separately, and frequently used as an inferior sole leather. It is also to be remarked that horse hides and *kips* (the hides of small foreign cattle) are frequently subjected to a process called *bate shaving*, in which the stout parts are reduced by a *currier's* knife previous to tanning, the object being to secure the complete infiltration of the animal fibre by the tannin in every part of the hide in the same time.

Sheepskins are usually pressed after the wool is removed, and before the tanning process is commenced, to get rid of the fatty matter contained in them, and which is not readily removed by ordinary *working*.

In all the above processes, as the animal fibres on the surface of the skin absorb most readily the tanning principles, and thereby obstruct, in a certain degree, their passage into the interior fibres, especially of thick hides, it becomes an object of importance to contrive some method of overcoming that obstacle, and promoting the penetration of the tan. The first manufacturer who appears to have employed efficacious mechanical means of favouring the chemical action was Francis G. Spilsbury, who in April, 1823, obtained a patent for the following operation: — After the hides are freed from the hairs, &c. in the usual way, they are minutely inspected as to their soundness, and if any holes be found, they are carefully sewed up, so as to be water tight. Three frames of wood are provided of equal dimensions, fitted to each other, with the edges of the frames held together by screw bolts. A skin about to be tanned is now laid upon the frame, and stretched over its edges, then the second frame is to be placed upon it, so that the edges of the two frames may pinch the skin all round and hold it securely; another such skin is then stretched over the upper surface of the second frame, in like manner, and a third frame being set upon this, confines the second skin. The three frames are then pinched tightly together by a series of screw bolts, passing through ears set round their outer edges, which fix the skin in a proper manner for being operated upon by the tanning liquor.

A space has been thus formed between the two skins, into which, when the frames are set upright, the infusion is introduced by means of a pipe from the cistern above, while the air is permitted to escape by a stopcock below. This cock must of course be shut whenever the bag is filled, but the one above is left open to maintain a communication with the liquor cistern, and to allow the hydrostatic pressure to force the liquor through the cutaneous pores by a slow infiltration, and thus to bring the tannin into contact with all the fibres indiscriminately. The action of this pressure is evinced by a constant perspiration on the outer surfaces of the skins.

When the tanning is completed, the upper stopcock is closed, and the under is opened to run off the liquor. The frames are now removed, the bolts are unscrewed, and the pinched edges of the skins pared off; after which they are to be dried and finished in the usual manner.

A modification of this ingenious and effectual process was made the subject of a patent, by William Drake, of Bedminster, tanner, in October, 1831. The hides, after the usual preparatory processes, are immersed in a weak tan liquor, and by frequent handling or turning over, receive an incipient tanning before being submitted to the infiltration plan. Two hides, as nearly of the same size and shape as possible, are placed grain to grain, when their corresponding edges are sewed firmly together all round by shoemaker's waxed thread, so as to form a bag sufficiently tight to hold tan liquor. This bag must then be suspended by means of loops sewed to its shoulder end, upon pegs, in such a manner that it may hang within a wooden-barred rack, and be confined laterally into a book form. About an inch of the bag is left unsewed at the upper end, for the purpose of introducing a funnel through which the cold tan liquor is poured into the bag till it be full. After a certain interval, which varies with the quality of the hides, the outer surface becomes moist, and drops begin to form at the bottom of the bag. These are received in a proper vessel, and when they accumulate sufficiently may be poured back into the funnel; the bag being thus, as well as by a fresh supply from above, kept constantly distended.

When the hides are observed to feel hard and firm, while every part of them feels equally damp, the air of the tanning apartment, having been always well ventilated, is now to be heated by proper means to a temperature gradually increasing from 70° to 150° of Fahrenheit's scale. This heat is to be maintained till the hides become firmer and harder in all parts. When they begin to assume a black appearance in some parts, and when the tan liquor undergoes little diminution, the hides may be considered to be tanned, and the bag may be emptied by cutting a few stitches at its bottom. The outer edges being pared off, the hides are to be finished in the usual way. During their suspension within the racks, the hides should be shifted a little sideways, to prevent the formation of furrows by the bars, and to facilitate the equable action of the liquor.

By this process the patentee says, that a hide may be tanned as completely in ten days as it could be in ten months by the usual method.

Messrs. Knowlys and Duesbury obtained a patent in August, 1826, for accelerating the impregnation of skins with tannin, by suspending them in a close vessel, from which the air is to be extracted by an air pump, and then the tanning infusion is to be admitted. In this way, it is supposed to penetrate the hide so effectually as to tan it uniformly in a short time.

Danish leather is made by tanning lamb and kid skins with willow bark, whence it derives an agreeable smell. It is chiefly worked up into gloves.

Of the tawing or dressing of skins for gloves, and white sheep leather.

The operations of this art are: 1, washing the skins; 2, properly treating them with lime; 3, taking off the fleece; 4, treatment in the leather steep.

A shed erected upon the side of a stream, with a cistern of water for washing the skins; wooden horses for cleaning them with the back of the fleshing knife; pincers for removing the fibres of damaged wool; a plunger for depressing the skins in the pits; a lime pit; a pole with a bag tied to the end of it; a two-handled fleshing knife; a rolling pin, from 15 to 18 inches long, thickened in the middle. Such are some of the utensils of a tawing establishment. There must be provided also a table for applying the oil to the skins; a fulling mill, worked by a water-wheel or other power; a dressing peg; a press for squeezing out the fatty filth; a stove; planks mounted upon legs, for stretching the skins, &c.

Fresh skins must be worked immediately after being washed, and then dried, otherwise they ferment, and contract either indelible spots, or get tender in certain points, so as to open up and tear under the tools. When received in the dry state they should be steeped in water for two days, and then treated as fresh skins. They are next strongly rubbed on the convex horse-beam with a round-edged knife, in order to make them pliant. The rough parts are removed by the fleshing knife. One workman can in this way prepare 200 skins in a day.

The flesh side of each being rubbed with a cold cream of lime, the skins are piled together with the woolly side of each pair outermost, and the flesh sides in contact. They are left in this state for a few days, till it is found that the wool may be easily removed by *plucking*.

They are next washed in running water, to separate the greater part of the lime, stripped of the wool by small spring tweezers, and then fleeced smooth by means of the rolling-pin, or sometimes by rubbing with a whetstone. Unless they be fleeced soon after the treatment with lime, they do not well admit of this operation subsequently, as they are apt to get hard.

They are now steeped in the milk of lime-pit, in order to swell, soften, and cleanse them; afterwards in a weak pit of old lime-water, from which they are taken out and drained. This steeping and draining upon inclined tables, are repeated frequently during the space of 3 weeks. Only the skins of young animals, or those of inferior value are tawed. Sometimes the wool is left on, as for housings, &c.

The skins, after having been well softened in the steeps, are rubbed on the outside with a whetstone set in a wooden case with two handles, in order to smoothe them completely by removing any remaining filaments of wool. Lamb skins are rubbed with the pin in the direction of their breadth, to give them suppleness; but sheep skins are fulled with water alone. They are now ready for the *branning*, which is done by mixing 40lbs. of bran with 20 gallons of water, and keeping them in this fermentable mixture for three weeks—with the addition, if possible, of some old bran water. Here they must be frequently turned over, and carefully watched, as it is a delicate operation. In the course of two days in summer, and eight in winter, the skins are said to be *raised*, when they sink in the water. On coming out of the bran, they are ready for the white stuff; which is a bath composed of alum and sea-salt. Twelve, fourteen, and sometimes eighteen pounds of alum for 100 skins, form the basis of the bath; to which two and a half pounds of salt are added in winter, and three in summer. These ingredients are introduced into a copper with twelve gallons of water. The salt aids in the whitening action. When the solution is about to boil, three gallons of it are passed through the cullender into a basin; in this 26 skins are worked one after another, and after draining, they are put together into the bath, and left in it for ten minutes to imbibe the salts. They are now ready to receive the paste. For 100 skins, from 13 to 15 pounds of wheat flour are used, along with the yolks of 50 eggs. After having warmed the alum bath through which the skins have been passed, the flour is dusted into it, with careful stirring. The paste is well kneaded by the gradual addition of the solution, and passed through the cullender, whereby it becomes as clear as honey. To this the yolks being added, the whole is incorporated with much manual labour. The skins are worked one after another in this paste; and afterwards the whole together are left immersed in it for a day. They are now stretched and dried upon poles, in a proper apartment, during from 8 to 15 days, according to the season.

The effects of the paste are to whiten the skins, to soften them, and to protect them from the hardening influence of the atmosphere, which would naturally render them brittle. They would not bear working upon the *softening iron*, but for the emulsion which has been introduced into their substance. With this view they are dipped in a tub of clear water during five or six minutes, and then spread and worked upon the board. They are increased by this means in length, in the proportion of 5 to 3. No hard points must be left in them. The whiteness is also better brought out by this

operation, which is performed upon the flesh side. The softening tool is an iron plate, about one foot broad, rounded over above, mounted upon an upright beam, 30 inches high, which is fixed to the end of a strong horizontal plank, 3½ feet long, and 1 broad. This plank is heavily loaded, to make it immovable upon the floor. Sometimes the skins are next spread over an undressed clean skin upon the horse, and worked well with the two-handled knife, for the purpose of removing the first and second epidermis, called the *fleur* and *arrière-fleur* by the French *megissiers*. They are then dried while stretched by hooks and strings. When dry they are worked on the *stretching-iron*, or they are occasionally polished with pumice stone. A delicate yellow tint is given by a composition made of two parts of whitening and one of ochre, applied in a moistened state, and well worked in upon the grain side. After being polished with pumice, they are smoothed with a hot iron, as the laundresses do linen, whereby they acquire a degree of lustre, and are ready to be delivered to the *glover*.

For *housings*, the best sheepskins are selected, and such as are covered with the longest and most beautiful fleece. They are steeped in water, in order to be cleaned and softened; after which they are thinned inside by the fleshing knife. They are now steeped in an old bran pit for 3 or 4 days, when they are taken out and washed. They are next subjected to the white or alum bath, the wool being carefully folded within; about 18 pounds of alum being used for 100 skins. The paste is made as for the fleeced skins, but it is merely spread upon their flesh side, and left upon them for 18 hours, so as to stiffen. They are then hung up to dry. They are next moistened by sprinkling cold water upon them, folded up, piled in a heap, and covered with boards weighted with heavy stones; in which state they remain for two days. They are next opened with a round iron upon the horse, and subjected to the stretching iron, being worked broadwise. They are dried with the fleece outermost, in the sun if possible, and are finished upon the *stretcher*.

Calf and lamb skins with their hair and wool are worked nearly in the same manner; only the thicker the skin, the stronger the alum bath ought to be. One pound of alum and one of salt are required for a single calf skin. It is left four days in this bath, after which it is worked upon the *stretcher*, then fulled. When half dry, the skins are opened upon the horse. In eight days of ordinary weather, they may be completely dressed. Lamb skins are sometimes steeped during eight days in a bath prepared with unbolted rye flour and cold water, in which they are daily moved about two or three times. They are then dried, stretched upon the iron, and switched upon the fleecy side.

Chamois, or *Shamoy leather*.—The skins are first washed, limed, fleeced, and branned as above described. They are next *efflowered*, that is, deprived of their epidermis by a concave knife, blunt in its middle part, upon the convex horse-beam. The cutting part serves to remove all excrescences, and to equalise the thickness, while the blunt part softens and smooths. The skins of goats, does, and chamois are always treated in this way. They are next subjected to the fermenting bran steep for one or two days, in ordinary weather; but in hot weather for a much shorter time, sometimes only moving them in the sour bran liquor for a few minutes. They are lastly wrung at the peg, and subjected to the fulling mill.

When the skins have been sufficiently swelled and suppled by the branning, they may receive the first oil as follows: a dozen skins being stretched upon the table, the fingers are dipped in the oil, and shaken over the skins in different places, so as to impart enough of it to imbue the whole surface slightly, by friction with the palms of the hands. It is to the outside or *grain* that the oil is applied. The skins are folded four together, so as to form balls of the size of a hog's bladder, and thrown into the trough of the fulling mill, to the number of twelve dozen at once. Here they remain exposed to the beater for two, three, or four hours, according to their nature and the state of the weather. They are taken out, aired, oiled, and again fulled. The airing and fulling are repeated several times, with more or less frequent oilings. Any cheap animal oil is employed.

After these operations, the skins require to be subjected to a fermenting process, to dilate their pores, and to facilitate their combination with the oil. This is performed in a chamber only 6 feet high, and 10 or 12 feet square. Poles are suspended horizontally a few inches from the ceiling, with hooks fixed in them to which the skins are attached. A somewhat elevated temperature is maintained, and by a stove if need be. This operation requires great skill and experience.

The remainder of the epidermis is next removed by a blunt concave knife and the horse; whereby the surface is not cut, but rather forcibly scraped.

The skins are now scoured to carry off the redundant oil; which is effected by a potash lye, at 2° Baumé, heated no hotter than the hand can bear. In this they are stirred briskly, steeped for an hour, and lastly wrung at the peg. The soapy liquor thus expelled is used for inferior purposes. The clean skins after being dried are finished first on the *stretcher-iron*, and then on the *horse* or stretching frame.

Leather of Hungary.—This is manufactured by impregnating strong hides with alum, common salt, and suet; by a rapid process which is usually completed in the space of two months. The workshop is divided into two parts; 1. A shed on the side of a stream, furnished with wooden horses, fleshing knives, and other small tools. In one corner is a furnace with a boiler for dissolving the alum, a vat for immersing the hides in the solution, and several subsidiary tubs. 2. A chamber, 6 feet high, by 15 feet square, capable of being made very tight, for preserving the heat. In one corner is a copper boiler, of sufficient size to contain 170 pounds of tallow. In the middle of the stove is a square stone slab, upon which an iron grate is placed about a yard square. This is covered with charcoal. At each side of the stove are large tables, which occupy its whole length, and on which the leather is spread to receive the grease. The upper part below the ceiling is filled with poles for hanging the leather upon to be heated. The door is made to shut perfectly close.

The first operations are analogous to those of tanning and tawing; the skins being washed, cut in halves, shaved, and steeped for 24 hours in the river. They are then cleaned with 5 or 6 pounds of alum, and 3½ pounds of salt, for a piece of hide which weighs from 70 to 80 pounds. The common salt softens the effect of the alum, attracts the moisture of the air, and preserves the suppleness of the skin. When the alum and salt are dissolved, hot water is poured upon the hides placed in a vat, and they are trampled upon by a workman walking repeatedly from one end of the vat to the other. They are then transferred into a similar vat containing some hot water, and similarly trampled upon. They are next steeped for eight days in alum water. The same round of operations is repeated a second time.

The skins are now dried either in the air, or a stove room; but before being quite dry, they are doubled together, well stretched to take out the wrinkles, and piled up. When dry, they are again trampled to open the pores as well as to render the skin pliant, after which they are whitened by exposure to the sun.

Tallow of inferior quality is employed for greasing the leather. With this view the hides are hung upon the poles in the close stove room, then laid upon the table, and besmeared with the tallow melted till it begins to crackle. This piece is laid on another table, is there covered with a second, similarly greased, and so forth. Three pounds of fat are commonly employed for one piece of leather.

When the thirty strips, or fifteen hides passed through the grease in one operation are completed, two workmen take the first piece in their hands, and stretch it over the burning charcoal on the grate for a minute, with the flesh side to the fire. The rest are passed over the flame in like manner. After *flaming*, the pieces are successively laid on an inclined table exposed to the fire, where they are covered with a cloth. They are finally hung upon poles in the air to dry; and if the weather be warm, they are suspended only during the night, so as to favour the hardening of the grease. Instead of the alum bath, M. Curaudau has employed with advantage a steep of dilute sulphuric acid.

Russia leather.—The Russians have long been possessed of a method of making a peculiar leather, called by them *jucten*, dyed red with the aromatic saunders wood. This article has been much sought after, on account of not being subject to mould in damp situations, being proof against insects, and even repelling them from the vicinity of its odour. The skins are freed from the hair or fleece, by steeping in an ash-lye too weak to act upon the animal fibres. They are then rinsed, fulled for a longer or shorter time according to their nature, and fermented in a proper steep, after having been washed in hot water. They are taken out at the end of a week, but they may be steeped a second time if deemed necessary, to open their pores. They are now cleaned by working them at the horse on both the flesh and grain sides.

A paste is next composed, for 200 skins, of 38 pounds of rye flour, which is set to ferment with leaven. This dough is worked up with a sufficient quantity of water to form a bath for the skins, in which they are soaked for 48 hours; they are then transferred into small tubs, where they remain during fifteen days, after which they are washed at the river. These operations serve to prepare the skins for absorbing the astringent juices with uniformity. A decoction of willow bark (*Salix cinerea* and *Salix caprea*) being made, the skins are immersed in the boiler whenever the temperature of the liquor is sufficiently lowered not to injure the animal fibres, and handled and pressed for half an hour. This manipulation is repeated twice daily during the period of a week. The tanning infusion is then renewed, and applied to the same skins for another week; after which, being exposed to the air to dry, they are ready for being dyed, and then curried with the empyreumatic oil of the bark of the birch tree. To this substance the Russia leather owes its peculiarities. Many modes have been prescribed for preparing it; but the following is the one practised in Russia.

The whitish membranous epidermis of the birch, stripped of all woody parts, is introduced into an iron boiler, which, when stuffed full, is covered tight with a vaulted

iron lid, having a pipe rising from its centre. A second boiler into which this pipe passes without reaching its bottom, is set over the first, and is luted to it at the edges, after the two are bolted together. They are then inverted, so that the upper one contains the birch bark. The under half of this apparatus is sunk in the earth, the surface of the upper boiler is coated over with a clay lute, then surrounded with a fire of wood, and exposed to a red heat, till the distillation be completed. This operation, though rude in appearance, and wasteful of wood, answers its purpose perfectly well. The iron cylinder apparatus used in Britain for distilling wood vinegar would, however, be much more convenient and productive. When the above bodies are unluted, there is found in the upper one a very light powder of charcoal, and in the under one, which served as a receiver, there is an oily, brown, empyreumatic fluid, of a very strong smell, which is mixed with the tar, and which floats over a small quantity of crude vinegar. The former matter is the oil employed to impregnate the skins, by working it into the flesh side with the currier's tools. It is difficult to make this oil penetrate with uniformity; and the Russians do not always succeed in this process, for they turn out many skins in a spotted state. This oil is at present obtained in France by distilling the birch bark in copper stills, and condensing the products by means of a pipe plunged in cold water. About 60 per cent. of the weight of the bark is extracted.

The skins imbibe this oil most equally before they are fully dry. Care must be taken not to apply too much of it, for fear of its passing through and staining the grain side of the leather. Chevreul has investigated the chemical nature of this odoriferous substance, and finding it to be a peculiar compound, has called it *betuline*.

In the Franklin Institute for February, 1843, Mr. Gideon Lee has published some judicious observations on the process of tanning. He believes that much of the original gelatine of the hides is never combined with the tannin, but is wasted; for he thinks that 100 lbs. of perfectly dry hide, when cleaned from extraneous matter, should, on chemical principles, afford at least 180 lbs. of leather. The usual preparation of the hide for tanning he believes to be a wasteful process. In the liming and bating, or the unhairing and the cleansing, the general plan is first to steep the hides in milk of lime for one, two, or three weeks, according to the weather and texture of the skin, until the hair and epidermis be so loosened as to be readily removed by rubbing down, by means of a knife, upon a beam or block. Another mode is to suspend the hides in a close chamber, heated slightly by a smouldering fire, till the epidermis gets loosened by incipient putrefaction. A third process, called sweating, used in Germany, consists in laying the hides in a pack or pile, covered with tan, to promote fermentative heat, and to loosen the epidermis and hairs. These plans, especially the two latter, are apt to injure the quality of the hides.

The *bate* consists in steeping the haired hides in a solution of pigeon's dung, containing, Mr. Lee says, muriate of ammonia, muriate of soda, &c.; but most probably phosphates of ammonia and lime, with urate of ammonia, and very fermentable animal matter. The dry hides are often subjected first of all to the operation of the fulling-stocks, which opens the pores, but at the same time prepares them for the action of the liming and bate; as also for the introduction of the tanning matter. When the fulling is too violent, the leather is apt to be too limber and thin. Mr. Lee conceives that the liming is injurious, by carrying off more or less of the gelatine and albumen of the skin. High-limed leather is loose, weighs light, and wears out quickly. The subsequent fermentation in the bating aggravates that evil. Another process has therefore been adopted in New York, Maine, New Hampshire, and some parts of Philadelphia, called, but incorrectly, *cool sweating*, which consists in suspending the hides in a subterranean vault, in a temperature of 50° Fahr., kept perfectly damp, by the trickling of cold spring water from points in the roof. The hides being first soaked, are suspended in this vault from 6 to 12 days, when the hair is well loosened, by the mere softening effect of moisture, without fermentation.—H. M.

LEATHER, MOROCCO. (*Maroquin*, Fr.; *Saffian*, Germ.) Morocco leather of the finer quality is made from goat-skins tanned with sumach; inferior morocco leather (roan) from sheep skins. The goat skins as imported are covered with hair; to remove which they are soaked in water for a certain time, and they are then subjected to the operation called breaking, which consists in scraping them clean and smooth on the flesh side, and they are next steeped in lime pits (milk of lime) for several days, during which period they are *drawn out*, with a hook, from time to time, laid on the side of the pit to drain, and replunged alternately, adding occasionally a little lime, whereby they are eventually deprived of their hair. When this has become sufficiently loose, the skins are taken out one by one, laid on convex beams, the work benches, which stand in an inclined position, resting on a stool at their upper end, at a height convenient for the workman's breast, who scrapes off the hair with a concave steel blade or knife, having a handle at each end. When unhaired, the skins are once more soaked in milk of lime for a few days, and then scraped on the flesh-

side to render it very even. For removing the lime which obstructs their pores, and would impede the tanning process, as well as to open these pores, the skins are steeped in a warm semi-putrid alkaline liquor, made with pigeons' and hens' dung diffused in water. Probably some very weak acid, such as fermented bran water, would answer as well, and not be so offensive to the workmen. (In Germany the skins are first washed in a barrel by a revolving axle and discs.) They are again scraped, and then sewed into bags, the grain outermost, like bladders, leaving a small orifice, into which the neck of a funnel is inserted, and through which is poured a certain quantity of a strong infusion of the sumach; and they are now rendered tight round the orifices, after being filled out with air, like a blown bladder. A parcel of these inflated skins are thrown into a very large tub, containing a weaker infusion of sumach, where they are rolled about in the midst of the liquor, to cause the infusion within to act upon their whole surface, as well as to expose their outsides uniformly to the tanning action of the bath. After a while these bladder skins are taken out of the bath, and piled over each other upon a wooden rack, whereby they undergo such pressure as to force the enclosed infusion to penetrate through their pores, and to bring the tannin of the sumach into intimate contact, and to form a chemical combination with the skin fibres. The tanning is completed by a repetition of the process of introducing some infusion or decoction into them, blowing them up, and floating them with agitation in the bath. In this way goat skins may be well tanned in the course of one day.

The bags are next undone by removing the sewing, the tanned skins are scraped as before on the curriers' bench, and hung up in the drying loft or shed; they are said now to be "in the crust." They are again moistened and smoothed with a rubbing tool before being subjected to the dyeing operations, in which two skins are applied face to face to confine the dye to one of their surfaces only, for the sake of economising the dyeing materials, which may be of several different colours. The dyed skins are grained by being strongly rubbed with a ball of box wood, finely grooved on its surface.

Preparatory to being dyed, each skin is sewed together edgewise, with the grain on the outside, and it is then mordanted either with a solution of tin, or with alum water. The colour is given by cochineal, of which from 10 to 12 ounces are required for a dozen of skins. The cochineal being boiled in water along with a little tartar or alum for a few minutes, forms a red liquor, which is filtered through a linen cloth, and put into a clean cask. The skins are immersed in this bath, and agitated in it for about half an hour; they are taken out and beaten, and then subjected to a second immersion in the cochineal bath. After being thus dyed, they are rinsed and tanned with Sicilian sumach, at the rate of two pounds for a skin of moderate size. The process is performed in a large tub made of white wood, in the liquor of which the skins are floated like so many bladders, and moved about by manual labour during four hours. They are then taken out, drained, and again subjected to the tanning liquor; the whole process requiring a space of twenty-four hours. The skins are now unstitched, rinsed, fulled with beetles, drained, rubbed hard with a copper blade, and lastly hung up to dry.

Some manufacturers brighten the colour by applying to the surface of the skins, in a damp state, a solution of carmine in ammonia with a sponge; others apply a decoction of saffron to enliven the scarlet tint. At Paris, the morocco leather is tanned by agitation with a decoction of sumach in large casks made to revolve upon a horizontal axis, like a barrel churn. White galls are sometimes substituted for sumach; a pound being used for a skin. The skins must be finally cleaned with the utmost care.

The black dye is given by applying with the brush a solution of red acetate of iron to the grain side. Blue is communicated by the common cold indigo vat; violet, with a light blue followed by cochineal red; green, by Saxon blue followed by a yellow dye, usually made with the chopped roots of the barberry. This plant serves also for yellows. To dye olive, the skins are first passed through a weak solution of green vitriol, and then through the decoction of barberry root, containing a little Saxon blue. Puce colour is communicated by logwood with a little alum; which may be modified by the addition of a little Brazil wood. In all these cases, whenever the skins are dyed, they should be rinsed, wrung, or rather drained, stretched upon a table, then besmeared on the grain side with a film of linseed oil applied by means of a sponge, in order to promote their glossiness when curried, and to prevent them becoming horny by too rapid drying.

The last process in preparing morocco leather is the currying, which brings out the lustre, and restores the original suppleness. This operation is practised in different manners, according to the purpose the skins are to serve. For pocket-books, portfolios, and case-making in general, they must be thinned as much as possible upon the flesh side, moistened slightly, then stretched upon the table, to smooth them; dried

again, moistened, and lastly passed two or three times through the cylinder press in different directions, to produce the crossing of the grain. The skins intended for the shoemaker, the saddler, the bookbinder, &c., require more pliancy, and must be differently curried. After being thinned, they are glazed with a polisher while still moist, and a grain is formed upon the flesh side with the roughened lead plate or grainer of the curriers, called in French *pommelle;* they are glazed anew to remove the roughness produced by the pommel, and finally grained on the flesh side with a surface of cork applied under a pommel of white wood.

Tawing of Skins. (*Megisserie*, Fr.; *Weissgerberei*, Germ.) The kid, sheep, and lamb skins, are cleaned as has been already described. In some factories they receive the tanning power of the submuriate of alumina (from a solution of alum and common salt) in a large barrel-churn apparatus, in which they are subjected to violent agitation, and thereby take the *aluming* in the course of a few minutes. In other cases, where the yolks of eggs are added to the above solution, the mixture, with the skins, is put into a large tub, and the whole trampled strongly by the naked feet of the operator, till the emulsion of the egg be forced into the pores of the skin. The tawed skins, when dry, are "staked," that is stretched, scraped, and smoothed by friction against the blunt edge of a semi-circular knife, fixed to the top of a short beam of wood set upright. The workman holding the extremities of the skin with both hands, pulls it in all directions forcibly, but skilfully, against the smoothing "stake."

In an entertaining article on tanning in the 11th vol. of the *Penny Magazine*, at page 215, the following description is given of one of the great tawing establishments of London.

"In the production of 'imitation' kid leather, the skin of lambs is employed; and for this purpose lamb-skins are imported from the shores of the Mediterranean. They are imported with the wool yet on them; and as this wool is valuable, the leather manufacturer removes this before the operations on the pelt commence. The wool is of a quality that would be greatly injured by the contact of lime, and therefore a kind of natural fermentation is brought about as a means of loosening the wool from the pelt." The following is a description of one of the buildings. "On the ground floor, a flight of stone steps leads down to a range of subterranean vaults or close rooms, into which the lamb-skins are introduced in a wet state, after having been steeped in water, 'broken' on the flesh side, and drained. The temperature of these rooms is nearly the same all the year round, a result obtained by having them excluded as much as possible from the variations of the external atmosphere; and the result is, that the skins undergo a kind of putrefactive or fermenting process, by which the wool becomes loosened from the pelt. During this chemical change ammonia is evolved in great abundance; the odour is strong and disagreeable; a lighted candle, if introduced, would be instantly extinguished, and injurious effects would be perceived by a person remaining long in one of the rooms. Each room is about ten feet square, and is provided with nails and bars whereon to hang the lamb-skins. The doors from all the rooms open into one common passage or vault, and are kept close, except when the skins are inspected. It is a point of much nicety to determine when the fermentation has proceeded to such an extent as to loosen the wool from the pelt; for if it be allowed to proceed beyond that stage, the pelt itself would become injured.

When the fermentation is completed, generally in about five days, the skins are removed to a beam, and there "slimed," that is, scraped on the flesh side, to remove a slimy substance which exudes from the pores. The wool is then taken off, cleaned, and sold to the hatters, for making the bodies of common hats. The stripped pelts are steeped in lime-water for about a week, to kill the grease; and are next "fleshed on the beam." After being placed in a "drench," or a solution of sour bran for some days to remove the lime and open the pores, the skins are alumed, and subjected to nearly the same processes as the true kid-skins. These Mediterranean lamb-skins do not in general measure more than about 20 inches by 12; and each one furnishes leather for two pairs of small gloves. These kinds of leather generally leave the leather-dresser in a white state; but undergo a process of dyeing, softening, "stroking," &c., before being cut up into gloves.

The tanning of one average-sized skin requires about 1¼ lbs. of good Sicilian sumach; but for leather which is to receive a bright scarlet dye, from one half to three quarters of a pound of gall-nuts are employed in preference. Inferior goat skins are tanned with a willow bark infusion, in pits, in which they are turned repeatedly, and laid out to drain, as in tanning sole leather. The finest skins for the brightest scarlet are cured with salt, to prevent their receiving damage in the transport, and are dyed before being tanned. This method is practised in Germany and France.

Leather of deer and sheep-skins is prepared with oil, for the purpose of making breeches, &c., and for wash-leather, used in cleaning plate. After they are completely

washed, limed, and beamed, as above described, they have their "grain"-surface removed, to give them greater softness and pliability. This removal of the grain is called "frizing," and it is done either with the round edge of a blunt knife, or with pumice-stone. After being freed from the lime by steeping in fermented bran-water, they are pressed as dry as may be, and are then impregnated with cod-oil, by beating with stocks in the trough of a kind of fulling mill. Previously to the application of the oil, they are usually beat for some time alone to open their substance. The oiled skins are stretched, hung up for some time in the air, then fulled with oil as before—a process which is 8 or 9 times repeated. The oil is slowly and evenly poured upon the skins in the trough during the action of the beaters. One hundred skins usually take up in this way from two to three gallons of oil. The fulled oil skins are thrown into large tubs, and left for some time to ferment, and thereby to combine more intimately with the oil. They are lastly subjected to a weak potash lye bath, to strip them of the loosely adhering oil. They are then hung up in the air to dry, and dressed for the market. — H. M.

LEATHER, RUSSIAN, *as tanned at Kazan*. The hides to be tanned may be either fresh from the animal or dry, no matter which; they are first laid to soak for 3 days and nights in a solution of potash, to which some quicklime is added. The potash used is made of the tree called in Russ *ilim* (the common elm), which sort is said to be preferable to any other, if not essential; it is not purified, so that it is of a brown colour and of an earthy appearance: about 12 poods of this (the pood is 36 lbs. English), and 2 poods of lime, serve for 100 skins. As they have no way of ascertaining the degree of causticity of the alkali but by its effect upon the tongue, when they find it weak they let the skins lie longer in the solution.

When the skins are taken out of this solution they are carried to the river, and left under water for a day and a night.

Next a vedro of dog's dung is boiled in as much water as is enough to soak 50 skins, (the vedro is equal to 2·696 English imperial gallons) but in the winter time, when the dung is frozen, twice that quantity is found necessary. The skins are put into this solution, not while it is boiling hot, but when at the heat which the hand can bear; in this they lie one day and one night.

The skins are then sewed up so as to leave no hole; in short, so as to be water-tight; about one third of what the skin will contain is then filled up with the leaves and small twigs chopped together of the plant called in Russ Toloknanka (*Arbutus uva-ursi*, sometimes called bear berry), which is brought from the environs of Solikamskaga, and the skin is then filled up with water.

The skins thus filled are laid one on the other in a large trough, and heavy stones upon them, so as by their weight to press the infusion through the pores of the skin in about 4 hours; yet, as it was said at the same time, that the skins are filled up with the same water which had been pressed out 10 times successively, and that the whole operation takes but one day and one night, this leaves but 2½ hours for each time.

The skins are then taken to the river and washed, and are ready for the dyeing. The whitest skins are laid aside for the red and yellow leather.

(The operations in dyeing follow, but are here omitted.)

To soften the skins after dyeing, they are harassed by a knife, the point of which is curved upwards.—H. M.

LEATHER, CURRYING OF. The currier's shop has no resemblance to the premises of the tanner, the tools and manipulations being quite different.

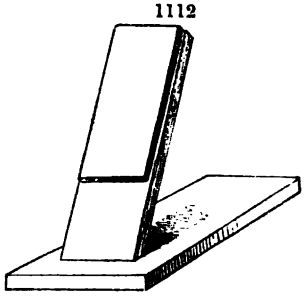
Within the last twenty or thirty years, many tanners have added the currying business to their establishments, and many curriers have likewise commenced tanning; but in each case, an extension of premises is necessary, and the two departments are still separate. The advantages derivable from this arrangement are two-fold,—first, a saving of time is effected, for as the tanned leather is sold by weight, it is required to be well dried before being disposed of to the currier, an operation which is not needed where the tanner carries on the currying also; and secondly, by the currier's art, the skins can be reduced to a comparatively uniform thickness previous to their being tanned, thus saving *time* and *bark* (used for tanning), and insuring a more equal distribution of tannin through the substance of the skin. In the following description, the business of currying will be considered as practised at the present time.

The currier's shop or premises, to be convenient, should be spacious. A frequent, though not universal method, is to have the ground-floor appropriated to such operations as require the use of a large quantity of water. The place or apartment thus used, is called the *scouring-house*, and is commonly furnished with a number of *vats* or *casks open at one end*, in which the leather is placed for the purpose of soaking, and undergoing such treatment as will be hereafter described. In this apartment also is placed a large, flat, slate stone, called a *scouring-stone*, or, more consistently, the

stone on which the leather is scoured. This stone, which has its face perfectly flat and smooth, and which should measure 8 or 9 feet in length, by 4½ broad, forms a table, supported generally by masonry, but sometimes by a strong frame of wood, so constructed, that the water, which is freely used in scouring, may drain off on the opposite side from that on which the workman is engaged; an inclination of about three or four inches on the width of the table, is sufficient for this purpose. Another piece of furniture very frequently found *in*, or *on the same floor with* the scouring-house, is a block of sandstone, in the form of a parallelopipedon, between 2 and 3 feet long, and 9 or 10 inches broad, the upper face of which is kept as near as possible a perfect plane; this stone is fixed at a convenient height on a strong trussel, and is called the *rub-stone*, because here the workman *rubs* or sharpens his knives and other tools. In some large establishments where the premises and water are heated by steam, the scouring-house will be found with a service of pipe leading to the various vats, and the boiler, for generating the steam, may be conveniently placed in or near this part of the building.

The floor above the scouring-house, in the arrangement here laid down, is what is specially designated *the shop*. The furniture in this department consists of a *beam*, (*fig.* 1112) on which the leather is *shaved*. It consists of a heavy block of wood, on which the workman stands, and into one end of which a stiff piece of wood is firmly mortised, at an angle of about 85°; this upright (so called) is about a foot wide, the height being greater or less, according to the height of the workman, each of whom has his beam adjusted to meet his convenience. On the front of the *upright*, a piece of deal is firmly screwed, to which is glued a face or plate of *lignum vitæ*, worked to perfect smoothness to agree with the edge of the knife used in the operation of shaving. It is of the greatest importance to the workman, to keep his *skin* from injury, that his knife and beam should be kept in good order. A *table* or *tables*, generally of mahogany, large planks of which are used for the purpose to avoid joints, may be said to form a necessary part of the furniture of this department. These tables are firmly fixed, to resist the pressure of the workman when using various tools; and as light is of the greatest consequence in the operations performed on them, they are usually placed so as to have windows in front of them. A high *trussel* is frequently used, across which the leather is thrown, after undergoing any of the processes, while the currier subjects other pieces to the same operation.

1112

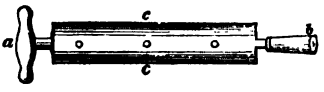


Another part of the premises is termed the *drying loft*. In good buildings the drying loft is surrounded with *weather-boards*, constructed to be opened or closed as may be required. The use of this part being the drying of the leather, the ceiling is furnished with a number of rails or long pieces of wood, with hooks or nails on which to hang the leather for drying, and where steam is used for this purpose, the floor is traversed with pipes for heating the *loft*. Here also is a table, similar to that previously described; it should not be less than 7 or 8 feet long by 4½ broad, if possible, without joint, and with a smooth face.

There are other subordinate departments, each furnished with a *table* similar to those described.

Of the tools used in currying, the *knife* stands first in importance (*fig.* 1113). Here *a* and *b* are two handles. *a* is held in the left hand, and forms a powerful lever when the edge *c* is applied to the leather. The blade of the currier's knife is peculiarly *tempered;* it is composed of a plate of fine steel, strongly riveted between two plates of iron. This instrument is taken to the *rub stone*, and ground to a perfectly sharp edge by successively rubbing forward and backward; care being taken to keep the edge *true*, that is, *straight*. When this has been satisfactorily accomplished, it is still further rubbed on a fine Scotch or Welsh stone called a *clearing-stone*, until the scratches of the *rub-stone* disappear.

1113



In this operation a fine thread or *wire* forms on the edges, for the knife has two edges (*c c*) which must be carefully got rid of; after which it is wiped dry, and the edges greased with tallow or oil. The workman then takes a strong steel, and placing himself on his knees, he fixes the knife with the straight handle *b* against any firm body, and the cross handle *a* between his knees; then holding the steel in both hands

he carefully rubs it forward and backward the whole length of the edge. During this operation the knife is gradually raised by means of the handle *a*, until it is nearly perpendicular; by this means the edge is turned completely over. If the knife is not well tempered, the edge thus obtained will be irregular, or broken; in either of which cases it is of no use whatever.

To keep the instrument just described in proper order requires great skill on the part of the currier. The edge is so delicate and liable to injury that it cannot be used more than a minute or two without losing its keenness. To restore this a very carefully prepared small steel is used, *fig.* 1114; the point of the steel is first run along the grove which is formed by turning the edge over, and the steel is then made to pass outside the edge (*fig.* 1210). It is remarkable that a skilful hand can thus restore the efficiency of the knife, and keep it in work for hours without going for a new edge to the *rub-stone*. The other tools will be described as their uses are mentioned.

1114

The first thing done by the currier is the soaking of the leather received from the tanner in water; the skin requires a thorough wetting, but not to saturation. In some cases the thicker parts are partially soaked before the immersion of the whole, and when from the nature of the skin this cannot be done, water is applied to the stout parts after the dipping; it is requisite that the whole should be as near as possible equally wet. In some instances the wetted leather is beaten, and sometimes a coarse graining-board (hereafter to be described) is used, to make it more supple previous to shaving it. The skin is then laid over the beam (*fig.* 1116) and the rough fleshy portion is shaved off. This operation is generally called *skiving*. In all the operations at the *beam* the leather is kept in its place by pressure of the knees or body of the workman from behind. In *skiving* the right hand handle of the knife somewhat precedes the left, but in *shaving*, properly so called, the left hand precedes the right, *fig.* 1117. In *skiving* the knife is driven obliquely a few inches at a time, in shaving it is driven with great force, not unfrequently from the top to the bottom of the beam; great skill is requisite in the performance of these operations, to guide the knife and to keep its edge. The carpenter's plane can be most completely regulated by the projection of the plane iron from the wood, but the currier's knife admits of no such arrangement, and the unskilful currier is constantly liable to injure the leather by cutting through it, as well as by failing to produce a regular substance. The

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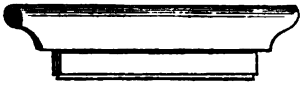
kind of skin, and the use for which it is designed will regulate the work at the beam. In some cases, as in the calf-skin, it is skived and then shaved, or, (as it is called) *flattened* at right angles to the skiving — in other kinds, as the cow-hide prepared for the upper leather of heavy shoes, after skiving it is *shaved across* (*i. e.* nearly at right angles to the skiving), and *flattened* by being again shaved in the same direction as the skiving. In some manufactories there are certain kinds of leather which are subjected to the operation called by curriers *stoning*, before *flattening*: this is done by forcibly driving the *stock-stone* (*fig.* 1118) over the *grain* side of the leather, thereby stretching it, and rendering the grain smooth. The *flattening* process is considerably facilitated by this stoning, and if the skin has been allowed slightly to harden by exposure to air, and the edge of the knife is fine, as it should be, the workman has but to strike the flat part of the knife over the leather after the shaving is performed, to produce a beautiful face to the flesh side of the skin. It will not be difficult to understand that

1118



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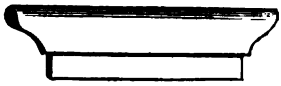


a good hand is easily distinguished from an inferior one in this part of the business. With such nicety will a skilful workman set the edge of his knife, that although there seems nothing to guide him, he can take shaving after shaving from the hide extending from the top to the bottom of the beam, thus rendering the leather extremely even in its substance.

After the process of shaving is completed, the leather is placed in water, where it remains until it is convenient to carry on the operation next required. It is to be observed that in the condition in which leather is shaved, it cannot long be kept without becoming heated; when, however, it is put into water, it is safe from injury, and may be kept a very long time, provided the water be occasionally changed for a fresh, sweet supply; stale water is regarded as injurious for the skin to remain in.

Scouring is next proceeded with; the skin is taken out of the water, and laid on the scouring-stone. In respectable manufactories, it is usual first to *scour on the flesh*; this is done by passing a *slicker* smartly over the flesh side, by which the *grain* of the leather is brought into close contact with the scouring-stone, and, being in a wet condition, the air is easily excluded, so that the leather *sticks* to the stone. A plentiful supply of water is now applied, and a large brush, with stiff hairs, is rubbed over the flesh, or upper side. Portions of the surface, in a pulpy condition, come off with the scrubbing, and the skin presents a soft, whitened, pulpy appearance; the pores are rendered capable of containing more moisture, and, altogether, the leather is much benefited. The *slicker* is a plate of iron or steel, or for particular purposes, of brass or copper; it is about five inches long, and like the *stock-stone*, is fixed in a stock, or handle (*fig.* 1119). It is sharpened at the *rub-stone*, by grinding the plate perpendicularly, and then on either side, thus producing two edges (or rather, *right angles*). The edges thus produced are not of an order to cut the leather, but rather to *scrape* it. The *slicker* is not intended to remove irregularities in the leather, but its uses are various, and it may be considered a very important tool as will hereafter appear.

In the process of *tanning*, the grain side of the hide or skin becomes covered with a whitish body, derived from the bark called *bloom*; this is more or less difficult to remove according to the hardness or softness of the water used in tanning, and the peculiar treatment of the tanner. It is, however, the currier's business to remove it, which he effects thus:—In the case of leather, whose grain is *tender*, as *cordovan*, which is manufactured from horse hides, the grain being kept uppermost, the leather is spread on the scouring-stone, and being plentifully supplied with water, is stretched by using the slicker, or a fine pebble, ground to the shape of the stock-stone, the *bloom* is thus loosened, and, at the same time, by making it adhere to the scouring-stone, the next operation is readily carried on, which consists in smartly brushing the grain with a stiff-haired brush, at the same time keeping a quantity of water on the surface, the slicker is again used to remove the water and loosened *bloom*, and the scouring is complete. In the scouring of calf-skins, and cow or ox hides, the stock-stone is used to fix the leather, and a piece of pumice-stone, the face of which has been ground to smoothness, and afterwards cut in grooves, is then forcibly rubbed over the grain, in order to remove the *bloom*. In this, as in other operations, on the scouring-stone, *water* is a necessary ingredient. The *bloom* being sufficiently loosened by the pumice-stone, the *brush* is used to scrub up the remaining dirt, which is then

removed by the stock-stone or slicker. In harness leather, which is stout, and requires to be stretched as much as possible, the pumice-stone is seldom used. the stock-stone and scouring-brush being lustily applied until the bloom is sufficiently removed. Ordinary manufacturers within the present (nineteenth) century, have considered the operations of the *scouring-house* complete at this point. The modern currier takes a different view, and not unfrequently detains his *scoured* property for days, and sometimes for weeks in the *scouring-house*.

If the leather is imperfectly tanned, or it is required to be made of a bright colour, there are other processes to be passed through. In these cases sumach (an evergreen shrub of the natural order *Anacardiaceæ*, genus *Rhus*, and from the bark of which all the leather made in Turkey is said to be tanned) is infused in boiling water, and when cooled to a tepid state the leather is placed in it. After staying a sufficient time it is taken to the scouring-stone; if *cordovan*, it is slicked as dry as can be well accomplished on the *flesh* side; other leather is for the most part slicked in a similar way on the grain side. Saddle leather which is required to be of a bright colour is still farther placed in warm water slightly acidulated with sulphuric or oxalic acid, or both; here for a time it is kept in motion, then taken to the scouring-stone, it is washed with peculiar chemical lotions, according to the taste or knowledge of the workman; then again it is dipped in tepid sumach infusion, then slicked with a copper or brass slicker (iron is liable to stain leather thus prepared), and a thin coat of oil being applied to either side it is removed to the *drying-loft*. Until within a very few years, much time and trouble were taken to produce *very bright* leather for the saddler; but of late, brown-coloured leather has been adopted to a considerable extent, as it is less liable to become soiled. Nearly all leather is placed a short time in the *loft* before farther manipulations are carried on, in order to harden it slightly by drying.

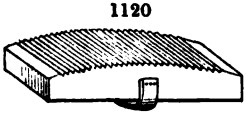
In the drying-loft, or its immediate vicinity, the leather receives the *dubbing* (*daubing, probably*) or *stuffing*. The substance so called is composed of tallow brought to a soft plastic condition by being melted and mixed with *cod-liver oil*; occasionally *sod* (an oil made in preparing sheep skins) is in very small quantities added to the mixture. This is laid upon the leather either with a soft haired brush or a mop made generally of rags.

The leather is prepared for stuffing by wetting slightly such parts as have become too dry. It is then taken to the table previously described, which being slightly oiled the process is carried on by placing the skin on the table in the manner most convenient for stretching it and making the surface smooth. In those kinds that have a rough wrinkled grain the flesh side is placed next the table and the *stock-stone* is used very smartly to stretch and smooth the grain. A kind of *clamp* or *holdfast*, composed of two cheeks fastened with a screw, is sometimes used to prevent the leather from moving during this operation, but in general these are not required; the slicker is then applied to remove the marks left by the *stock-stone*, and a thin stuffing being spread over the grain it is turned over, slicked on the flesh lightly, a coat of *stuffing* is spread over it, and it is hung up to dry. In those kinds which have to be blacked (or stained) on the *grain*, a little *cod oil* only is spread on the grain, and the slicker is applied on the flesh side most laboriously previous to *stuffing*. Much skill is required to give the requisite quantity of *stuff* (dubbing) to the leather without excess, excess being injurious, and the quantity required is farther regulated by the freshness or otherwise of the leather, the tan-yard from which it comes, and the treatment it has received in the scouring-house.

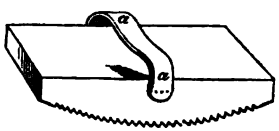
When dry, the skins or hides are folded together, to remain until required. It is certain the leather improves by remaining some weeks in this condition. It should be observed that, in drying, the leather absorbs a large quantity of the oleaginous matter with which it is charged, and the unabsorbed portion forms a thick coating of hardened greasy matter on the flesh side.

Leather which has to be blackened on the flesh (*wax leather*), from this point, receives different treatment from *grain* leather. *Wax* leather is taken to the *shop-table* and softened with a *graining-board*. The skin is laid on the table and doubled,

1120



1121



grain to grain, the *graining*-board (*fig.* 1121), which is confined to the hand by a leather strap (*a a*), is driven forward and drawn back alternately until a grain is raised on the

leather, and it has attained the required suppleness. Observe, the graining-board is slightly rounded on the lower surface, and traversed by parallel grooves from side to side, which are coarser or finer, as occasion requires. The grease is next removed from the flesh by the slicker, and afterwards a sharp slicker is passed over the grain to remove grease or other accumulations from it. The next process is called *whitening*. The leather is laid over the *beam*, and a *knife* with an extremely fine edge is used to take a thin shaving from the flesh side; this is a point at which a currier's skill is tested. The knife used is one that has been very much worn, the quality of which has been tested to the utmost; and so extremely *true* is the edge expected, that not the slightest mark (*scratch*) is allowed to appear on the surface of the leather. Only a good workman can satisfactorily accomplish this. The slightest gravel in the flesh of the skin may break the edge of the knife in pieces, and it is not easy to rectify so serious a misfortune; besides, a poor workman may tear up the edge by *steeling*, an operation which ought to mend the mischief instead of provoking it.

A fine *graining-board* is next used to soften the leather; the stiffer parts being *boarded* both on the grain and flesh sides, and the operation being carried on in two or three directions, to insure both softness and regularity of grain. *Boarding* is performed by doubling the leather and driving the double part forward and drawing it backward by the graining-board.

The leather is now prepared for the *waxer*, and passes, consequently, into his hands. Waxing, in large establishments, is a branch considered separate from the general business, and is usually in the hands of a person who confines himself to this occupation alone. The skin is laid on a table and the *colour* rubbed into the flesh side with a brush. It is necessary to give the brush a kind of circular motion to insure the required blackness in the leather. The *colour* is made by stirring a quantity of the best lampblack into *cod-liver oil;* sometimes a little *dubbing* is added, and in order to make it work smoothly so as not to clog the brush, some stale *tan water* from the vats in the scouring house is *beaten up* with the mixture until it combines therewith. The preparation of the *colour* is an important affair, and requires a considerable amount of time and labour to render it such as the *waxer* desires.

A *slick-stone*, or *glass*, is next used; this tool is about the size and shape of the slicker, but instead of being ground like it, the edges are very carefully removed, so that while, from end to end, it preserves nearly a right line, it is circular *across* the edge. The *stone* (a fine pebble) is little used now, plate-glass being substituted for it. The use of the tool just described is to smooth the flesh after the operation by the colouring brush, thereby getting rid of any marks made on the surface.

The next step in waxing is what is called *sizing*. Size is prepared by boiling glue in water—the melted glue is diluted with water to the extent required—in some cases it is softened by mixing *cod-liver oil* with it in cooling. When cold, it is beaten up with various ingredients, according to the taste or experience of the waxer; the waxer then well rubs the size into the coloured side of the leather, and with a sponge, or, more generally, the fleshy part of his hand, smooths it off. When dry, the *slick-stone*, or *glass*, is again applied, thus producing a polish on the size; and a very thin coat of oil completes the work. In different manufactories different methods are pursued, but the above is convenient and satisfactory in almost all circumstances. It is now ready for the shoemaker.

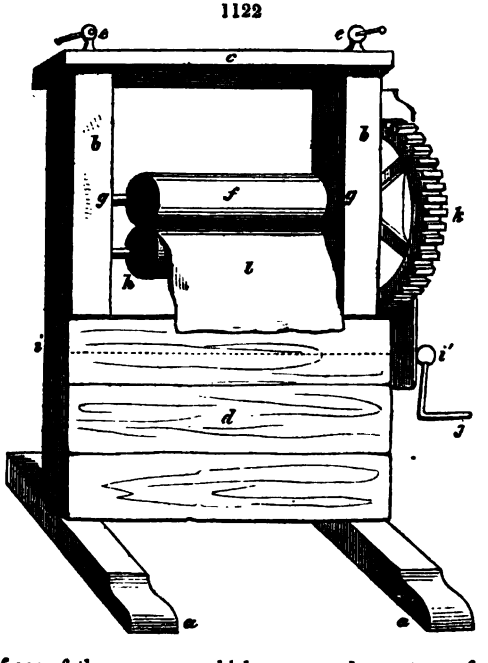
Leather intended to be blacked on the grain, is left folded up when dry after stuffing. Some years ago it was the custom to stain these kinds of leather, while wet in the scouring-house, by spreading stale urine over it and then applying a solution of *copperas* (sulphate of iron). That method is now exploded. The dry skins or pieces of leather are laid on the shop-board: a brush is used to saturate the *grain* with urine, or as is now more common, a *solution of soda in water*, and a peculiar preparation of *iron in solution* is afterwards laid over it, which blackens the surface. It may be observed that in wax-leather a body of black is laid on, and rubbed into the flesh; in grain leather the black is a stain. After the blackening, it is necessary to rub a small quantity of oil or *dubbing* over the blackened surface, then turning the oiled grain toward the table, a sharp slicker is used on the flesh side; the leather sticks to the table by means of the oil, and the slicker is driven so smartly over it, that it is *stretched* on the table, at the same time that the grease is removed. It is quite an important point to take *all the stretch* out of the leather in this operation, after which it is turned over; the table is covered with a very thin coat of hard tallow, a roll of tallow being rubbed over the table, for the purpose of keeping the leather fastened to it. A *dull* slicker is used on the grain to remove remaining marks and wrinkles, or to smooth any coarse appearance on the grain; a sharp slicker removes all the grease, and a thin coat of weak size, made of glue dissolved in water, is spread over it and the process, usually called *seasoning*, is completed. The next object is carefully to dry the *seasoned* leather, and in this state it may be stored without injury.

The next step is very similar to that described in the case of *wax-leather*, and called whitening:—it is then softened by means of a fine graining-board, or a board of the same shape and size covered with cork, the grain side is placed next the table, and the flesh doubled against the flesh, and thus driven forward and backward until the required degree of suppleness is obtained. The loose particles of flesh are brushed off and a slicker carefully passed over the grain removes all *marks* of the last operation. If a sufficiency of *stuff* has not been applied in the drying-loft, the deficiency is remedied by a coat of *tallow-dubbing* now spread over the grain and allowed to remain some hours. As the leather absorbs the oily matter a hardened coat of grease has to be removed by the aid of the slicker. The leather is then *sized*, and a very thin coat of oil spread over the size, completes the operation.

In the preparation of various kinds of leather, or of leather for particular purposes, the currier has particular appliances. Harness leather is considerably dryer than other kinds before stuffing, and is subjected to immense labour by the stock-stone and slicker, to procure a smooth grain. It is blackened when dry like other *grain* leather, but instead of the oiling and other processes described, the hardest tallow procurable is rubbed into it, *stoned* with a fine pebble, slicked, and tallow again rubbed into it by the hand. When dry after this operation, the grease is slicked from the flesh side, and a repetition of the tallowing, stoning, and rubbing finishes the work.

Saddle leather, which is cut into comparatively small pieces, after hardening in the drying loft, is passed through a very different process from any described previously. The skin of the hog is much used for certain parts of hackney saddles, and the bristles, when removed by the tanner, leave indentations, or even holes in the tanned skin. Probably it was deemed desirable to obtain some imitation for the parts of the saddle where the hog skin was not suitable. The skin of the dog-fish (*Scyllium*, Cuv.), to some extent supplied the imitation, having hard tubercles on its surface. At first the skin was laid on the leather and lustily pressed into it by rubbing it with a pebble or plate of glass; at length a press was invented, and more recently various methods have been proposed to produce the best effect. We have here (*fig.* 1122) a

1122

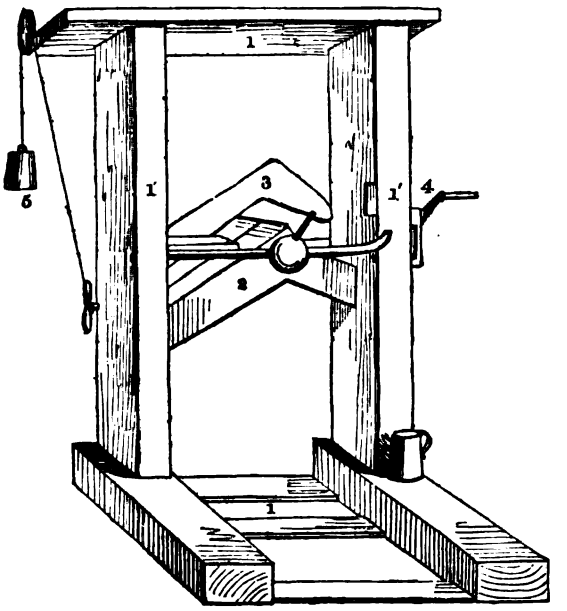


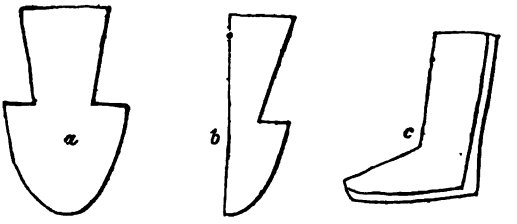
representation of one of these presses, which may stand as a type of all others; *a a* are the feet into which the uprights are inserted; *b b* are the two upright sides tied at the top by *c*, a similar cross piece ties them a little above the feet; *d* is a leaf fastened with hinges, which closes upon *c* when the press is not in use; *e e* are screws which press on the iron plate, in which the axes of the roller *f* are inserted; these plates imbedded in the uprights *b b* have considerable *play*, so as to allow the rollers *f h*

more or less pressure as the case may require. The dotted line *i i'*, represents an iron bar or cylinder, supplied with a small cog wheel at *i'*, and a *crank-handle j*, this is turned round by the hand, and the small cog wheel acts on a larger one *k*, which is attached to the axis of the roller *f*: *f* is a solid roller of hard wood, such as *lignum vitæ*; upon this cylinder is strongly glued the *fish skin*, previously alluded to; *h* is a cylindrical solid piece of wood covered with stout flannel; *l* is a piece of leather on which the leather to be pressed is placed; when all is adjusted the piece to be pressed is placed on *l*, the handle is moved slowly round, and the whole is carried between the rollers; the leather thus receives the imprint of the *fish skin*, and at the same time becomes extremely solid. After drying, this is fit for the saddler.

Of late years the currier has undertaken an office which was previously the business of the boot maker; namely, the *blocking* of boot fronts. This is performed by the instrument represented by *fig.* 1123. The leather is first dressed, as previously

1123

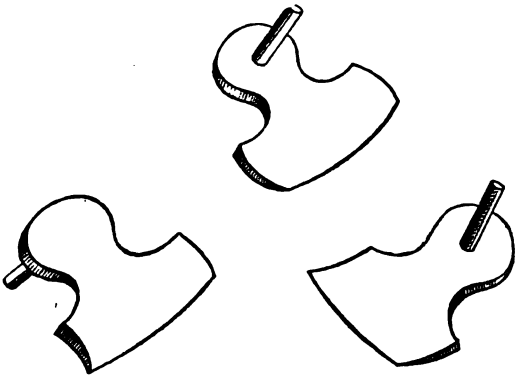




described, up to the point of being ready for *whitening*. The fronts are then cut (*fig.* 1123 *a*), and when folded or doubled appear as *fig.* 1123 *b*. 1' 1', 1 1, is a strong frame-work; 2, represents a pair of cheeks, strongly fastened in the frame, and regulated as to *distance* by a screw; these cheeks are lined with zinc; 3 is a strong plate of metal, the angle at 3 corresponding exactly with the angle of the cheeks; the ends of this plate are fixed in movable plates passing down the columns 1' 1'; 4 is a handle by which the instrument is worked, and which by cog-wheels acting on the movable plates brings 3 downwards. The *front*, *a*, is laid, after a thorough soaking in water,

over the cheeks 2, the handle being turned, 3 comes down upon the *front*, and forces it through the small opening between the cheeks, and when brought out below the cheeks, it has the appearance here given (*fig.* 1123 *c*). The plate 3 having carried the front between the cheeks, is removed (*below*), and the weight 5 assists in bringing the perpendicular movable plates to their place, when 3 is again put in position; and thus the operation is rapidly carried on. After this the *fronts* are regularly placed on a *block*, being forced into position by an instrument called the *flounder* (*fig.* 1124) and *tacked* to their place; after this they are slightly oiled and

1124



dried. Some ingenious methods have been adopted for softening the fronts, so as not to disturb the *blocking*. They are whitened on a very sloping *beam* (*fig.* 1125), which enables the workman to hold them better than he could on the common beam. They

1125

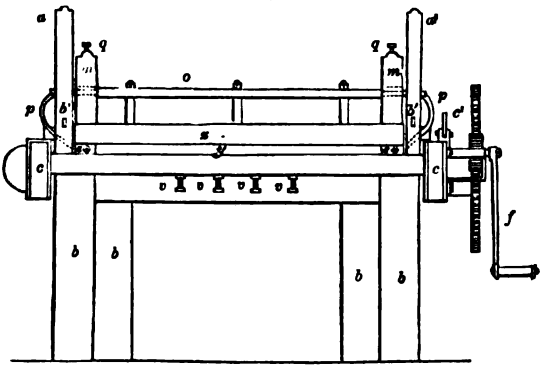
are again *blocked* by the *waxer*, and when these processes are carefully performed, much trouble is saved to the boot-maker. Of course, in a manufactory many appliances are found which are not here mentioned; the general idea, however, may be easily gathered from this description. The work is dirty and very laborious, requiring great skill and experience, and consequently good workmen have generally commanded better wages than other mechanics.

Hides intended for covering coaches are shaved as thin as shoe hides, and blacked on the grain.—H. M.

LEATHER SPLITTING. This operation is employed sometimes upon certain sorts of leather for glovers, for bookbinders, sheath-makers, and always to give a uniform thickness to the leather destined for the cotton and wool card-makers.

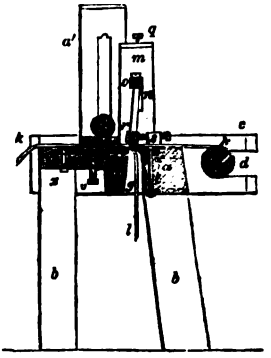
Figs. 1126, 1127, 1128, 1129 represent a well contrived machine for that purpose, of which *fig.* 1126 shows the front view, *fig.* 1127 a view from the left side, *fig.* 1129 a ground plan, and *fig.* 1128 a vertical section across the machine. *a* is a strong table, furnished with four legs *b*, which to the right and left hand bears two horizontal pieces *c*.

1126

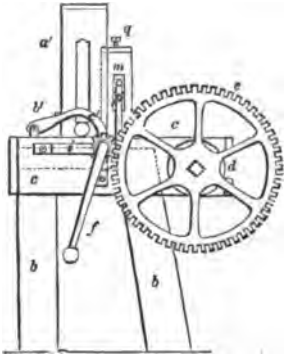


Each of these pieces is cut out in front, so as to form in its substance a half-round fork, that receives a cylinder *d*, carrying on its end a toothed spur-wheel *e*. Motion is communicated to the wheel by means of the handle *f*, upon whose axis the pinion *i* is fixed,

1128



1127



working into the wheel *d*, made fast to the end of the cylinder round which the leather is rolled. The leather is fixed at one of its ends or edges to the cylinder, either with a wedge pressed into a groove, or by a movable segment of the cylinder itself.

The table, *a*, is cut out lengthwise with a slot, that is widened below, as shown in *fig.* 1128.

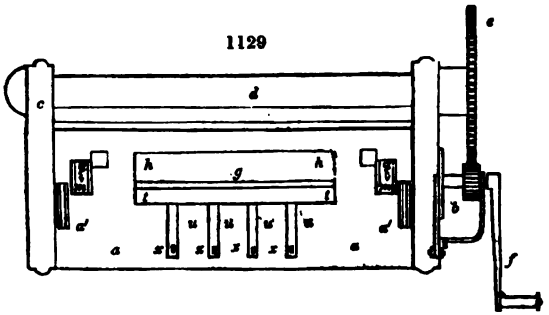
The knife *h* (*figs.* 1128 and 1129) is fixed flat upon the table with screw bolts, whose heads are countersunk into the table, and secured with taps beneath (*fig.* 1128), the edge of the knife being placed horizontally over the opening, and parallel with it.

In *fig.* 1128 the leather, *k*, is shown advancing against the knife, getting split, and has a portion coiled round the cylinder, which is made to revolve in proportion as the leather is cleft. The upper portion of the leather is rolled upon the cylinder *d*, while the under half, *l*, falls through the oblong opening upon the ground.

In regulating the thickness of the split leather, the two supports, *m*, act; they are made fast to the table *a* (one on each side of the knife), and are mortised into the table by two tenons secured beneath. These supports are furnished near their tops with keyed slots, by means of which the horizontal iron rod *o* (*figs.* 1126, 1128) is secured,

and outside of the uprights they press upon the springs *p p*, which tend to raise the rod, *o*, in its two end slots; but the adjusting screws *q*, which pass down through the tops of the

1129



supports into the mortise *n* (*fig.* 1128), and press upon the upper half of the divided tenon, counteract the springs, and accordingly keep the rod *o* exactly at any desired height or level. The iron rod *o* carries another iron bar, *r*, beneath it, parallel and also rectangular, *fig.* 1128. This lower bar, which is rounded at its under face, lies upon and presses the leather by the action of two screws, which pass through two upright pieces *s* (*figs.* 1126 and 1128) made fast to the table; thus the iron bar *r* may be made to press forwards the edge of the knife, and it may be adjusted in its degree of pressure, according to the desired thickness of the leaf of split leather that passes through under it.

Fig. 1128 shows that the slant or obliquity of the knife is directed downwards, over one of the edges of the oblong opening *g*; the other edge of this opening is provided with an iron plate *t* (*figs.* 1128, 1129), which serves to guide the blade in cutting the leather to the proper depth. For this purpose the plate is made adjustible by means of the four springs *u* (*fig.* 1129) let into the table, which press it downwards. Four screws, *v*, pass down through the table, each belonging to its respective spring *u*, and by means of these screws the plate *t* may be raised in any desired degree. Each of the screws *u* has besides a small rectangular notch through which a screw bolt *x* passes, by which the spring is made fast to the table. Thus also the plate *t* may be made to approach to or recede from the knife.

y, in *figs.* 1126 and 1128, is a flat board, laid upon the leather a little behind the edge of the plate *t*; this board is pressed by the cylinder *z*, that lies upon it, and whose tenons rest in mortises cut out in the two supports *a'*. The cylinder *z* is held in its position by a wedge or pin, *b* (*figs.* 1126 and 1127), which passes through the supports. When the leather has been split, these pins are removed, and the cylinder rises then by means of two counter-weights, not shown in the figures.

The operation of the machine is as follows:—The edge or end of the leather being secured to the cylinder *d*, the leather itself having the direction upon the table shown in *fig.* 1128, and the bar *r* its proper position over the knife, the edge begins to enter in this position into the leather, while the cylinder *d* is moved by the handle or winch, and the piece gets split betwixt the blade and the roller *d*. When the other end of the leather, *k*, advances to the knife, there is, consequently, one half of the leather split; the skin is to be then rolled off the cylinder *d*; it is turned; the already split half, or the end of the leather, *k*, is made fast into the wood of the cylinder, and the other half is next split; while the knife now acts from below, in an opposite direction to what it did at first.

That the unrolling of the leather from the cylinder, *d*, may not be obstructed by the pinion *i*, the stop-wedge *e* (*figs.* 1126, 1127) is removed from the teeth. In the process of splitting, the grain side of the leather is uppermost, and is therefore cut of an uniform thickness, but the under side varies in thickness with the inequality of the skin.

Several other ingenious contrivances have been introduced for this purpose, illustrated descriptions of which have been given by Hebert, who states that a splitting-machine, long used by the Messrs. Bevington, of Bermondsey, had been made to split sheepskins into three equal parts, one of which, that on the grain side, might be used as leather; the middle portion converted into parchment; and the slice on the flesh side, being unequal in thickness, and therefore unfit for any better use, being used for glue making. In this machine the skin is drawn between two revolving rollers, and presented, as it emerges from their grasp, to the edge of a long and very sharp knife, which is kept continually moving a little backwards and forwards with great velocity. As a skin of unequal thickness could not be grasped in the proper manner between two

perfectly true and rigid rollers, the upper roller, instead of being solid, is composed of a number of circular discs or rings of metal, about half an inch thick, slipped on to an axis rather smaller than the holes in their centres, but compelled to revolve with it by means of what may be termed a planetary axis, which is a rod passing loosely through holes in the whole series of discs, between their centre and their circumference, and so connected with the axis by its ends as to be carried round with it. By this contrivance the upper roller is enabled to adapt its surface to that of the skin, which is everywhere pressed with an equal force, due to the weight of the discs of which the upper roller is composed. It is stated in the *Penny Magazine* "that this machine will split a sheepskin of the ordinary size in about two minutes, during which time the knife makes from two to three thousand vibratory motions to and fro." This machine is said to be the invention of Lieutenant Parr. Another contrivance is known as Duxbury's Patent Skin Splitting Machine, in which the knife consists of a series of plates of steel, so attached to the periphery of a wheel or disc, seventeen feet in diameter, as to form a gigantic cutting instrument, resembling a crown or trepan saw, the compound blade projecting horizontally from the rim of the wheel parallel to its axis. The skin to be split passes round the circumference of a horizontal drum, the axis of which is at right angles with that of the great disc, and lies very nearly in the same plane with its face, and which instead of being perfectly cylindrical has its sides so hollowed as to present a concavity perfectly tallying with the curvature of the periphery of the disc. As therefore the drum revolves it brings the skin, which is confined closely to its concave surface by a contrivance somewhat resembling the upper roller in the machine above described, in contact with the edge of the revolving knife, which cuts by a continuous onward movement, instead of a sawing action backwards and forwards. The extreme nicety required to fix the concavity of the feeding roller to the edge of the circular knife, and to keep the knife or cutter itself perfectly true in shape, appear to be the chief objections to this ingenious contrivance.—*Penny. Cyc., Suppl., Leather.*

Exports of Leather of British Produce and Manufacture in 1850 and 1851:—

		Quantities.		Declared Value.	
				£	£
		1850.	1851.	1850.	1851.
Leather, unwrought -	cwts.	32,205	25,525	181,737	152,070
Wrought, viz. gloves -	lbs.	31,114	27,141	18,821	19,781
Of other sorts - -	lbs.	1,619,463	1,625,565	284,347	288,543
Saddlery and harness - -		—	—	123,960	138,186

It may not be uninteresting to compare these figures with the imports and exports in 1856 and 1857, ending December 1st.

Imports into the United Kingdom: —

		1856.	1857.
Hides, dry - - -	cwts.	219,370	297,783
Hides, salted - - -	„	427,734	16,766
Leather - - -	lbs.	3,493,589	5,500,010
Boot fronts - - -	pairs	646,154	606,992
Boots, shoes, and goloshes of all kinds - - -	pairs	182,485	200,661

The whole of which are free from import duty, except,

	s.	d.		s.	d.	
Boot fronts - - -	1	9	to	2	9	per dozen pairs.
Women's boots and shoes -	4	6	„	7	6	„
Men's do. do. -	7	0	„	14	0	„

Exports from the United Kingdom: —

		1856.	1857.
Hides, dry - - -	cwts.	128,952	121,600
Hides, salted - - -	„	37,996	59,413

British Manufacture.

		Quantities.		Declared value.	
				£	£
		1856.	1857.	1856.	1857.
Leather, unwrought -	cwts.	33,455	34,320	294,703	331,873
Leather, wrought -	lbs.	5,931,810	8,090,795	1,122,084	1,700,928
Saddlery and harness -	-	—	—	253,342	294,617

H. M.

LEATHER, VEGETABLE. Under this name a new material, composed of India rubber spread upon linen, has been introduced. Of this the *Mechanics' Magazine*

writes :—" Having seen some specimens of these leathers, as well as various articles of utility manufactured therewith, we have been induced to pay the extensive works of Messrs. Spill and Co., the eminent Government contractors, on Stepney-green, a visit, in order to cull sufficient to place upon record the present position of artificial as a substitute for real leather. The face and general character of the vegetable leather resembles the natural product so closely, that it is only by actual examination that the difference can be determined. This is more particularly the case in that description which is made for bookbinding, the covering of library tables, and like purposes. Amongst other advantages it possesses over leather proper, may be mentioned, that however thin the imitation is, it will not tear without considerable force is exercised; that it resists all damp, and that moisture may be left upon it for any period without injury, consequently, it does not sodden or cockle, is always dry, and its polish is rather increased than diminished by friction. Add to these facts, that any attempt to scratch or raise its surface with the nail, or by contact with any ordinary substance, will not abrade it, and enough will have been said to justify its entering the list against an article of daily use, which has of late years been deemed far from sufficient for the demand, and has consequently risen in price to the manifest loss and injury of every class of the community. We believe that the largest entire piece of real leather that can be cut from a bullock's hide, is not more than 7 feet by 5 feet, and this includes the stomach and other inferior parts. Vegetable leather on the contrary, is now produced 50 yards in length, and 1½ yard wide, every portion being of equal and of any required thickness, and the smallest portion is convertible. We were agreeably disappointed, however, to find that instead of vegetable leather being a discovery requiring the aid of ourselves and contemporaries, it was, although so young, an active agent in the fabrication of numerous articles of daily requirement, and that it had already become the subject of large, indeed we may say enormous, contracts. Caoutchouc and naphtha are used in its manufacture; but by a process known to the senior of the firm, who is himself an accomplished chemist, all odour is removed from the naphtha, and the smell of vegetable leather is rendered thereby less in strength, if anything, than that of leather. The principal objects to which it is at present applied, although it is obvious it will take a wider range of usefulness than leather itself, are carriage and horse aprons, antigropola, soldier's belts, buckets which pack flat, harness of every description, bookbinding, &c. For, the latter, its toughness, washable quality and resistance to stains, render it remarkably fitted. Its thickness, which may be carried to any extent, is obtained by additional backings of linen, &c., cemented with the caoutchouc, and its strength is something marvellous, while in the all-important commercial view, it is but one-third the price of leather. Many of the articles we were shown possessed the appearance of much elegance and finish; but it was curious to observe, that although most of them could be made without a stitch, and within the factory itself, a deference to the feelings of the workmen in the several trades has been shown by the firm, and the material is given out as ordinary leather, to undergo the process of the needle, which it submits to with a greater facility than its original prototype."

LEDUM PALUSTRE. This plant is employed in Russia to tan the skins of goats, calves, and sheep, into a reddish leather of an agreeable smell; as also in the preparation of the oil of birch, for making what is commonly called Russia leather.

LEER. An arched building, forming an annealing furnace, in which glass is tempered or annealled.

LEGUMINE is the name of a vegeto-alkali supposed to exist in leguminous plants.

LEMNIAN EARTH. A yellowish-grey earth, obtained from Lemnos by the Greeks. It is very similar to fuller's earth.

LEMONS. The fruit of the *Citrus limonum*. Both the juice and the peel of the fruit are employed medicinally, and in the preparation of lemonade. The quantity of lemons imported cannot be ascertained from the Custom House returns, as they are reckoned together with oranges. See CITRIC ACID, and OILS, ESSENTIAL.

LENS. (*Lentille*, Fr.; *Linsenglas*, Germ.) Lenses are transparent bodies, usually made of glass, which by their curvature either concentrate or disperse the rays of light. Lenses are of the following kinds. *Double convex*, having the same or a different degree of convexity on either side. *Plano convex*, having one plane and one convex surface. *Concavo convex*, having one concave and one convex side, commonly called *meniscus* lenses. *Plano concave*, having one plane surface and one concave one; and the *double concave* lens.

The first three, which are thicker in the middle than at the edge, are *converging lenses*, because they occasion the rays of light to converge in passing through them. The others which are thicker at the edges than in the middle, and therefore cause the pencils of light refracted through them to diverge, are called diverging lenses.

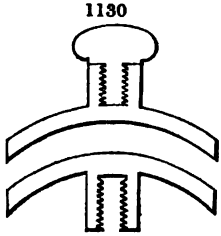
For the most complete examination of the laws regulating the construction of lenses, and the action of these on the rays of light we must refer the reader to Sir John

Herschel's admirable treatise on *Light* in the *Encyclopedia Metropolitana*. In this work we have only to deal with the mode of manufacturing the ordinary varieties. The spherical surfaces are produced by grinding them in counterpart tools, or discs of metal, prepared to the same curvature as the lenses. For the formation of the grinding tools, a concave and a convex template are first made to the radius of the curvature of the required lens. The templates of large radius, are sometimes cut out of crown glass. More usually the templates are made out of sheet brass, the templates of long radii are cut with a strong radius bar and cutter, and those of only a few inches radius are cut in the turning lathe. The brass concave and convex gauges are cut at separate operations, as it is necessary to adjust the radius to compensate for the thickness of the cutter, and the brass templates are not usually corrected by grinding, as practically it is found more convenient to fit the tools themselves together. The templates having been made of the required radius, are used for the preparation of the grinding and polishing tools, which for concave lenses consist of a concave rough grinding tool of cast iron called a *shell*.

A pair of brass tools is however the most important part of the apparatus. One of these is concave and the other convex, made exactly to the curvature of the templates and to fit each other as accurately as possible. The concave tool is used as the grinder for correcting the curvature of the lenses after they have been roughly figured in the concave shell, and the convex tool is employed for producing and maintaining the true form of the concave grinding tool itself, and also that of the polisher. These polishers are adjusted with great accuracy. The concave tool is placed upon the convex, and they are first rubbed together dry, so that by the brightened parts the inequalities may be distinguished, they are then ground true, first by means of emery and water, and then with dry emery.

The following figure (1130) represents those tools, which are fitted with screws at the back so that they can be fixed upon pillars, in connection with the machinery for giving motion to them.

1130



By grinding with sundry niceties of motion which are required to produce the best effect, such as the production of motion which shall resemble as nearly as possible the kind of stroke which would be given by the hand, these tools are eventually brought to true spherical figures which fit each other exactly.

The glasses for lenses, being selected of suitable quality, they are brought to a circular form by means of flat pliers called *shanks*. The pressure of the pliers applied near the edges of the glass causes it to crumble away in small fragments, and this process, which is called *shanking* or nibbling, is continued until the glasses are made circular, and of a little larger diameter than the finished size of the lenses.

A cement is made by mixing wood ashes with melted pitch. Some nicety is required in the adjustment of the proportion, since the cement must not be too adhesive, nor must it be too hard or too brittle; generally about 4 lbs. of wood ashes to 14 lbs. of pitch are employed. This when melted is poured on one side of the glasses to be ground, in small quantities at a time, until a sufficient quantity adheres to the back of the lens to form a handle. The glass is rough ground by rubbing it within the spherical shell. The glass is rubbed with large circular strokes, and the *shell* is usually placed within a shallow tray to catch the loose emery or polishing powder which may be employed. When one side is rough ground in this way, the glass is warmed to detach it from the handle, which is transferred to the other side and the operation repeated. When both sides are thus rudely formed, the lenses are cemented upon a runner. The best object glasses for telescopes are ground and polished singly, while as many as four dozen of common spectacle glasses are ground and polished together. When many are thus fixed on one runner, the number must be such as will admit of their being arranged symmetrically around a central lens, as 7, 13, or 21, or sometimes 4 form the nucleus, and then the numbers run 14, 30. Lenses of ordinary quality are usually ground true and polished seven at a time. This runner with its lenses attached is shown in *fig.* 1131.

1131

The cement at the back of the lenses is first flattened with a heated iron. The cast iron runner is heated just sufficiently to melt the cement, and carefully placed upon the cemented backs of the lenses. As soon as the cement is sufficiently softened to adhere firmly to the runner, it is cooled with a wet sponge, as the cement must only be so far fused as to fill up the spaces nearly, but not quite, level with the surface of the lenses. The block of lenses is now mounted upon a post, and ground with the concave brass tool, *fig.* 1130, motion being given to it either by the hand or by

machinery similar to the sweeping motion already named. As the grinding proceeds, the fineness of the emery powder employed is increased, until in the last operation it is sufficiently fine to produce a semi-polished surface. This grinding being completed successfully, the lenses have to be polished. The polisher is made by warming a cast iron shell and coating it uniformly about one quarter of an inch thick with melted cement. A piece of thick woollen cloth is cut to the size of the polisher and secured to it, and pressed into form by working the brass tool within it. When this is properly adjusted it is covered with very finely divided putty powder, sprinkled with a little water, and the powder worked into the pores of the cloth with the brass convex tool. Repeated supplies of putty powder is put on the polisher until it is made quite level, and it is worked smooth with the tool. Many hours are expended in the proper preparation of a polisher. When completed it is placed upon the block of lenses still fixed to the post, and worked with wide and narrow elliptical strokes. Where a very large number of glasses are ground or polished at the same time, this peculiar motion is imitated by the eccentric movement of a lever attached to the revolving shaft. In the processes of grinding and polishing, other materials beside emery and putty powder are sometimes employed, such as *raddle*, an earthy oxide of iron, the finer kinds of which are much employed in the large lens manufactory at Sheffield.

Much more might be said on the subject of grinding and polishing lenses, but it is one of those processes of manufacture which scarcely come within the limits of the present work. Still it was thought to be of sufficient importance to receive some general notice. The grinding and polishing of the finer varieties of lenses for telescopes, microscopes, and the like, require extremely nice manipulation. The best account of the processes and of the instruments used is one by the late Andrew Ross in the fifty-third volume of the *Transactions of the Society of Arts*. In *Holtzapffel's Mechanical Manipulation* there is also some very excellent practical information. See LIGHTHOUSE; PHOTOGRAPHY.

LEPIDINE, $C^{28}H^9N$. A volatile base, homologous with chinoline, found in coal naphtha and in the fluid produced by distilling cinchonine with potash.—C. G. W.

LEUCITE. A mineral found in volcanic rocks, containing usually 56·10 of silica, 23·10 of alumina, and 21·15 of potash.

LEUCOLINE. A compound of $C^{18}H^9N$, produced during the destructive distillation of coal. See COAL GAS.

LEUKOL. See CHINOLINE.

LEVEL (*a mining term*). An adit gallery or horizontal working in a mine.

LEVIGATION is the mechanical process whereby hard substances are reduced to a very fine powder.

LEWIS is the name of one kind of shears used in cropping woollen cloth.

LIAS. Under this term are comprehended the strata which intervene between the Trias, or New Red Series, and the Inferior Oolite. In the aggregate they are of considerable thickness, and occupy a large area in this country, stretching in a north-easterly direction from the sea west of Lyme Regis, in Dorsetshire, to Redcar, on the coast of Yorkshire. The strata which compose the Liassic series consist, in the lower part, of compact argillaceous limestone, alternating with or forming *layers* in clay, to a provincial pronunciation of which word the name *lias* probably owes its origin. This limestone forms the base of a thick deposit of blue clays and marls, which are overlaid by a series of sands and sandstone, called Marlstone; these in their turn, are separated from another mass of sands, which form the uppermost member of the group, by a stratum of clay, known as the Upper Lias Clay.

By the term lias, however, is ordinarily only understood the calcareous and argillaceous division, which constitutes the lower section of the entire formation.

In an economical point of view, it is of considerable value from its furnishing a useful and durable stone, both for building and paving; for the latter purpose it is particularly suited, not only from the large dimensions of the flags it affords, but on account of its occurrence in thin layers, which, in many cases, when required for rough purposes only, are used in the state in which they are taken from the quarry, without undergoing subsequent dressing. The lime furnished by the blue lias limestone, is also well known, and in great request, some of the beds possessing the valuable property of forming hydraulic mortars and cements, for manufacturing which it is collected from the shore and the sea cliffs at Charmouth, and largely quarried at Lyme Regis and the neighbourhood.

The clayey members of the lias furnish a poor and cold agricultural soil, which is chiefly devoted to pasture, but the land upon the marlstone is, on the contrary, of a very rich and fertile description, and constitutes a district, where it prevails, that is marked by the luxuriance of its crops, and the excellence of the cider it produces. In the upper part, it contains beds of ferruginous, brown, calcareous sandstone, which

is used for building purposes in the neighbourhoods where it occurs. The sandstone is always more or less of a ferruginous character, but in some instances the ferruginous ingredient prevails to such a degree, as to constitute a valuable ore of iron, as in the neighbourhood of Blenheim, to which attention has lately been directed by Mr. Edward Hull, of the geological survey of Great Britain.

Like the marlstone, the calcareous sands of the uppermost portion of the liassic series also furnish a rich agricultural soil. Until recently, these sands were considered to form the base of the inferior oolite series, but the researches of Dr. Wright, render it highly probable that they should, with more propriety, be classed with the underlying lias, rather than with the oolitic strata.*

The stone found at Cotham and other places in the neighbourhood of Bristol, and which has in consequence received the name of *Cotham marble*, and has also been called *ruin*, or *landscape marble*, from the curious delineations displayed upon polished sections of it, resembling trees, landscapes, &c., is a limestone from the lower part of the lias.—H. W. B.

LIBAVIUS, FUMING LIQUOR OF, is the bichloride of tin, prepared by dissolving that metal with the aid of heat in *aqua regia*, or by passing chlorine gas through a solution of muriate of tin till no more gas be absorbed, evaporating the solution, and setting it aside to crystallise. The anhydrous bichloride is best prepared by mixing four parts of corrosive sublimate with one part of tin, previously amalgamated with just so much mercury as to render it pulverisable; and by distilling this mixture with a gentle heat. A colourless fluid, the dry bichloride of tin, or the proper fuming liquor of Libavius, comes over. When it is mixed with one-third of its weight of water it becomes solid. The first bichloride of tin is used in calico-printing. See CALICO-PRINTING.

LICHEN. A certain set of plants, composed chiefly of cellular tissue devoid of spinal vessels, with the stems and leaves undistinguishable, are termed Thallogens. These are of two kinds, the first admitting of two divisions:—

1. *Aquatic* thallogens, or such as are nourished through their whole surface by water, are ALGÆ. *Aerial* thallogens nourished through their whole surface by air are LICHENS.

2. Thallogens nourished through their *thallus* (spawn or mycelium) by juices derived from the matrix are FUNGI.

Lichens are numerous, as *Ground liverwort*, *Cup moss*, *Tree lungwort*, used in Siberia as a substitute for hops in brewing; *Gyrophora* employed by the hunters in the arctic regions as an article of food, under the name of *tripe de roche*; *Reindeer moss*, *Iceland moss*, much used in this country as a remedy for coughs; the *Common yellow wall lichen*, and some others.

The *Tinctorial lichens* are also numerous. They furnish four principal colours, brown, yellow, purple, and blue.

Gyrophora pustulata and *Sticta pulmonaria* yield brown colours. The latter, with mordants of tin and cream of tartar, produces on silk a durable carmelite colour. (*Guibourt.*)

Parmelia parietina and *Evernia vulpina* produce yellows, the yellow principle of the former being called *chrysophanic acid*, that of the latter *vulpinic acid*.

Rocella, *Lecanora*, *Variolaria*, &c., yield purple and blue colours. In this country archil and cudbear, purple colours, are prepared. In Holland, a blue colour, litmus.

The following is a list (from *Pereira*) of the principal lichens employed by British manufacturers of archil and cudbear, with their commercial names:—

ORCHELLA WEEDS.

Angola Orchella weed (*R. fuciformis*).
Madagascar „ „
Mauritius „ „
Canary „ (*R. tinctoria*).
Cape de Verd „ „
Azores „ „
Madeira „ (ditto and *fuciformis*).
South America, large and round (*R. tinctoria*).
South America, small and flat (*R. fuciformis*).
Cape of Good Hope (*R. hypomecha*).
Barbary (Mogadore) (*R. tinctoria*).
Corsican and Sardinian „

MOSSES.

Tartareous (*Lecanora tartarea*).
Postulatus (*Gyrophora pustulata*).
Canary Rock (*Parmelia perlata*).
Corsican.
Sardinian.
Norway Rock Moss.

Dr. Stenhouse, to whom we are much indebted for many important inquiries connected with the applications of chemistry, has given the following table of the lichens:—

* The evidence brought foward by Dr. Wright in favour of the liassic origin of these sands is purely of a palæontological nature; physically, the most natural arrangement is to connect them rather with the inferior oolite than with the lias.—H. W. B.

Lichens.		Colorific Principles.		Colouring Principles.		Authority.
Commercial Names.	Locality.	Names.	Formulæ.	Names.	Formulæ.	
S. American orchella weed.	Lima, &c.	Alpha orsellic acid.	$C^{32}H^{15}O^{13}+HO$.	Orceine.	$C^{18}H^{10}NO$.	Stenhouse.
Cape orchella weed	C. of Good Hope.	Beta orsellic acid.	$C^{34}H^{18}O^{14}+HO$.	,,	,,	Stenhouse.
Angola orchella weed.	Africa.	Erythric acid.	$C^{20}H^{10}O^{9}+HO$.	,,	,,	Stenhouse.
Perelle moss (*Lecanora parella.*)	Switzerland	Lecanoric acid.	$C^{16}H^{8}O^{8}$.	,,	,,	Shunck.
Tartareous moss (*Lecanora tartarea.*)	Norway.	Gyrophoric acid.	$C^{36}H^{18}O^{18}$.	,,	,,	Stenhouse.
Pustulatous moss (*Gyrophora pustulata*).	Norway.	,,	,,	,,	,,	Stenhouse.
Ragged hoary lichen (*Evernia prunastri*).	Scotland.	Evernic acid.	$C^{34}H^{15}O^{13}+HO$.	- -	- -	Stenhouse.
Usnea(*Florida, plicata*, and *hirta*).	Germany.	Usnic acid.	$C^{36}H^{7}O^{14}$.	- -	- -	Rochleder and Heldt.
Rein deer moss (*Cladonia rangiferina*).	- -	,,	,,	- -	- -	,,
Ramalina (*Fastigiata calicaris*).	- -	,,	,,	- -	- -	,,

See LITMUS, ORCHELLA WEED.

LICKNER'S BLUE. The Silicate of Cobalt and Potash.

LIGHT. (*Lumière*, Fr.; *Licht*, Germ.) The operation of light as an agent in the arts or manufactures has scarcely yet received attention. Sufficient evidence has however been collected to show that it is of the utmost importance in producing many of the remarkable changes in bodies which are desired in some cases as the result, but which, in others, are to be if possible avoided.

There is a very general misconception as to the power or principle to which certain phenomena, the result of exposure to sunshine, are to be referred. In general *light* is regarded as the principle in action, whereas frequently it has nothing whatever to do with the change. A few words therefore in explanation are necessary. The solar ray, commonly spoken of as *light*, contains in addition to its *luminous power*, *calorific power*, *chemical power*, and in all probability *electrical power*. (See ACTINISM.) These phenomena can be separated one from the other, and individually studied. All the photographic phenomena are dependent upon the chemical (actinic) power. Many of the peculiar changes which are effected in organic bodies are evidently due to light, and the phenomena which depend entirely on heat are well known.

Herschel has directed attention to some of the most striking phenomena of *light*, especially its action upon vegetable colours. As these have direct reference to the permanence of dyes, they are deserving of great attention. The following quotation from Sir John Herschel's paper "*On the Chemical Action of the Rays of the Solar Spectrum, &c.*" will explain his views and give the character of the phenomena which he has studied. He writes —

"The evidence we have obtained by the foregoing experiments of the existence of chemical actions of very different and to a certain extent opposite characters at the opposite extremities (or rather as we ought to express it in the opposite regions) of the spectrum, will naturally give rise to many interesting speculations and conclusions, of which those I am about to state, will probably not be regarded as among the least so. We all know that colours of vegetable origin are usually considered to be destroyed and whitened by the continual action of light. The process, however, is too slow to be made the subject of any satisfactory series of experiments, and, in consequence, this subject, so interesting to the painter, the dyer, and the general artist, has been allowed to remain uninvestigated. As soon, however, as these evidences of a counterbalance of mutually opposing actions, in the elements of which the solar light consists, offered themselves to view, it occurred to me, as a reasonable subject of inquiry, whether this slow destruction of vegetable tints might not be due to the feeble amount of residual action outstanding after imperfect mutual compensation, in the ordinary way in which such colours are presented to light, *i. e.* to mixed rays. It appeared therefore to merit inquiry, whether such colours, subjected to the uncompensated action of the elementary rays of the spectrum, might not undergo changes differing both in kind and in degree which mixed light produces on them, and might not, moreover, by such changes indicate chemical properties in the rays themselves hitherto unknown.

"One of the most intense and beautiful of the vegetable blues is that yielded by the

blue petals of the dark velvety varieties of the common heartsease (*Viola tricolor*). It is best extracted by alcohol. The alcoholic tincture so obtained, after a few days keeping in a stoppered phial, loses its fine blue colour, and changes to a pallid brownish red, like that of port wine discoloured by age.

"When spread on paper it hardly tinges it at first, and might be supposed to have lost all colouring virtue, but that a few drops of very dilute sulphuric acid sprinkled over it, indicate by the beautiful and intense rose colour developed where they fall, the continued existence of the colouring principle. As the paper so moistened with the tincture dries, however, the original blue colour begins to appear, and when quite dry is full and rich. The tincture by long keeping loses this quality, and does not seem capable of being restored. But the paper preserves its colour well, and is even rather remarkable among vegetable colours for its permanence in the dark or in common daylight.

"A paper so tinged of a very fine and full blue colour, was exposed to the solar spectrum concentrated, as usual (October 11, 1839), by a prism and lens; a water-prism, however, was used in the experiment, to command as large an area of sunbeam as possible. The sun was poor and desultory; nevertheless in half an hour there was an evident commencement of whitening from the fiducial yellow ray to the mean red. In two hours and a half, the sunshine continuing very much interrupted by clouds, the effect was marked by a considerable white patch extending from the extreme red to the end of the violet ray, but not traceable beyond that limit. Its commencement and termination were, however, very feeble, graduating off insensibly; but at the maximum, which occurred a little below the fiducial point (corresponding nearly with the orange rays of the luminous spectrum), the blue colour was completely discharged. Beyond the violet there was no indication of increase of colour, or of any other action. I do not find that this paper is discoloured by mere radiant heat unaccompanied with light."

Dr. George Wilson of Edinburgh made some exceedingly interesting experiments *on the influence of sun light over the action of the dry gases on organic colours*. The results arrived at were communicated to the British Association, and an abstract of the communication is published in their transactions. The experiments were on chlorine, sulphurous acid, sulphuretted hydrogen, carbonic acid, and a mixture of sulphurous and carbonic acid, oxygen, hydrogen and nitrogen on organic colouring matters. "I had ascertained," says Dr. George Wilson, "the action of the gases mentioned already on vegetable colouring matters, so arranged, that both colouring matter and gas should be as dry as possible, the aim of the inquiry being to elucidate the theory of bleaching, by accounting for the action of dry chlorine upon dry colours. In the course of this inquiry, I ascertained that in darkness dry chlorine may be kept for three years in contact with colours without bleaching them, although when moist it destroys their tints in a few seconds (see BLEACHING); and I thought it desirable to ascertain whether dry chlorine was equally powerless as a bleacher when assisted by sunlight. The general result of the inquiry was, that a few weeks sufficed for the bleaching of a body by chlorine in sunlight, where months, I may even say years, would not avail in darkness." The form of the experiment was as follows. Four tubes were connected together so as to form a continuous canal, through which a current of gas could be sent. Each tube contained a small glass rod on which seven pieces of differently coloured papers were spiked. It is not necessary here to state the colours employed, suffice it to say, that all the tubes thus contained seven different coloured papers, of different origins, and easily distinguishable by the eye. They were arranged in the same order in each tube, and were prepared as nearly as possible of the same shade. These papers were carefully deprived of every trace of moisture by a current of very dry air. The tubes were then filled with the gas, also dried, on which the experiment was to be made. One tube of each series was kept in darkness, two others were exposed in a western aspect behind glass, and the other was turned to the south in the open air.

The results were as follows: — In the dark chlorine tube the colours were very little altered, and would probably have been altered less had not the tube been frequently exposed to light for the sake of examination. In the western tube, the original grey and green wallflower papers became of a bright crimson, the blue litmus bright red, and the brown rhubarb yellow. The whole of the chlorine had apparently entered into combination with the colouring matters for the yellow tint of the gas had totally disappeared. In the southern tube the colour of the chlorine could still be seen, the reddening action was less decided, and the bleaching action was more powerfully evinced. The general result was that the action of sunlight is less uniform than might have been expected in increasing the bleaching power of chlorine, or while some tints rapidly disappeared under its action assisted by light, other colours remained, in apparently the very same circumstances, unaffected.

Sulphurous acid, if thoroughly dried, may be kept for months in contact with dry colours without altering them; under the influence of sunlight it however recovers to some extent its bleaching power.

Sulphuretted hydrogen acts as a weak acid, and readily as a bleacher when moist, and becomes inactive in both respects if made dry and kept in darkness. With the assistance of sunlight it recovers in no inconsiderable degree its bleaching power.

Oxygen is a well known bleaching agent, but when dry its action upon colouring matter in the dark is extremely slow. In sunlight, however, it recovers its bleaching power.

Carbonic acid, when dry in darkness, loses all power on colouring matter, but a faint bleaching action is exerted by it under exposure to sunlight.

Hydrogen is without any action when dry upon colours, but it acquires a slight decolorising power when exposed to sunshine.

"The general result," concludes Dr. George Wilson, "of this inquiry, so far as it has yet proceeded, is, that the bleaching gases, viz. chlorine, sulphurous acid, sulphuretted hydrogen, and oxygen, lose nearly all their bleaching power, if dry and in darkness, but all recover it, and chlorine in a most marked degree, by exposure to sunlight."

All these experiments appear to show that the action of the solar rays on vegetable colours is dependent upon the power possessed by one set of rays to aid in the oxidation or chemical changes of the organic compound constituting the colouring matter. The whole matter requires careful investigation.

It is a proved fact, that colouring matters, either from the mineral or the vegetable kingdoms, are much brighter when they are precipitated from their solutions in bright sunshine, than if precipitated on a cloudy day or in the dark. It must not be supposed that all the changes observed are due to chemical action; there can be no doubt but many are purely physical phenomena, that is, the result of molecular change, without any chemical disturbance.

LIGHT, ELECTRIC. See ELECTRIC LIGHT.

LIGHTHOUSE. The importance of lights of great power and of a distinguishable character around our coasts is admitted by all. One of the noblest efforts of humanity is certainly the construction of those guides to the mariners upon rocks which exist in the tracks of ships, or upon dangerous shores and the mouths of harbours. This is not the place to enter largely upon any special description of the lights which are adopted around our shores; a brief account only will be given of some of the more remarkable principles which have been introduced of late years by the Trinity Board.

The early lighthouses appear to have been illuminated by coal or wood fires contained in "chauffers." The Isle of Man light was of this kind until 1816. The first decided improvement was made by Argand, in 1784, who invented a lamp with a circular wick, the flame being supplied by an external and internal current of air. To make these lamps more effective for lighthouse illumination, and to prevent the ray of light escaping on all sides, a reflector was added in 1780 by M. Lenoir; this threw the light forward in parallel rays towards such points of the horizon as would be useful to the mariner. Good reflectors increase the luminous effect of a lamp about 400 times; this is the "catopric" system of lighting. When reflectors are used, there is a certain quantity of light lost, and the "dioptric" or *refracting* system, invented by the late M. Augustin Fresnel in 1822 is designed to obviate this effect to some extent: the "catadioptric" system is a still further improvement, and acts both by refraction and reflexion. Lights of the first order have an interior radius or focal distance of 36·22 inches, and are lighted by a lamp of four concentric wicks, consuming 570 gallons of oil per annum.

The appearance of light called short eclipses has hitherto been obtained by the following arrangement: —

An apparatus for a fixed light being provided, composed of a central cylinder and two zones of catadioptric rings forming a cupola and lower part, a certain number of lenses are arranged at equal distances from each other, placed upon an exterior movable frame making its revolution around the apparatus in a given period. These lenses, composed of vertical prisms, are of the same altitude as the cylinder, and the radius of their curves is in opposite directions to those of the cylinder, in such a manner that at their passage they converge into a parallel pencil of light, all the divergent rays emitted horizontally from the cylinder producing a brilliant effect, like that obtained by the use of annular lenses at the revolving lighthouses.

Before proceeding with the description of the lenses, the following notices may be of interest: —

The Eddystone Lighthouse 9½ miles from the Rame Head, on the coast of Cornwall, was erected of timber by Winstanley in 1696–98, and was washed away in

1703. It was rebuilt by Rudyard in 1706, and destroyed by fire in 1755. The present edifice was erected by Smeaton 1757–59. Tallow candles were used in the first instance for the lights; but in 1807 argand lamps, with paraboloidal reflectors of silvered copper were substituted.

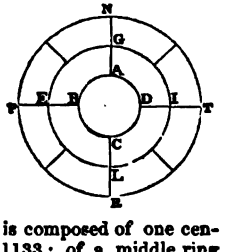
The Skerryvore Rocks, about 12 miles south-west of Tyree on the coast of Argyleshire, lying in the track of the shipping of Liverpool and of the Clyde had long been regarded with dread by the mariners frequenting these seas. The extreme difficulty of the position, exposed to the unbroken force of the Atlantic Ocean, had alone deterred the commissioners of northern lights from the attempt to place a light upon this dangerous spot; but in 1834 they caused the reef to be surveyed, and in 1838 Mr. Alan Stevenson, their engineer, inheriting his father's energy and scientific skill, commenced his operations upon a site from which "nothing could be seen for miles around but white foaming breakers, and nothing could be heard but the howling of the winds and the lashing of the waves." His design was an adaptation of Smeaton's tower of the Eddystone to the peculiar situation, a circumstance with which he had to contend. He established a circular base 42 feet in diameter, rising in a solid mass of gneiss or granite, but diminishing in diameter to the height of 26 feet, and presenting an even concave surface all around to the action of the waves. Immediately above this level the walls are 9·58 feet thick, diminishing in thickness as the tower rises to its highest elevation, where the walls are reduced to 2 feet in thickness, and the diameter to 16 feet. The tower is built of granite from the islands of Tyree and Mull, and its height from the base is 138 feet 8 inches. In the intervals left by the thickness of the walls are the stairs, a space for the necessary supply of stores, and a not uncomfortable habitation for three attendants. The rest of the establishment, stores, &c., are kept at the depôt in the island of Tyree. The light of the Skerryvore is revolving, and is produced by the revolution of eight annular lenses around a central lamp, and belongs to the first order of dioptric lights in the system of Fresnel, and may be seen from a vessel's deck at a distance of 18 miles. — *Lord De Mauley, Juror's Report, Great Exhibition*, 1851.

Some of the lenticular arrangements must now claim attention. Large lenses, or any large masses of glass, are liable to striæ, which by dispersing, occasion a loss of much light.

"In order to improve a solid lens formed of one piece of glass whose section is A, *m*, *p*, B, F, E, D, C, A, Buffon proposed to cut out all the glass left white in the figure (1132), namely, the portions between *m p* and *n o*, and between *n o* and the left hand surface of D E. A lens thus constructed would be incomparably superior to a solid one, but such a process we conceive to be impracticable on a large scale, from the extreme difficulty of polishing the surfaces A *m*, B *p*, C *n*, F *o*, and the left hand surface of D E; and even if it were practical, the greatest imperfections of the glass might happen to occur in the parts which are left. In order to remove these imperfections and to construct lenses of any size," says Sir David Brewster, "I proposed in 1811 to build them up of separate zones or rings, each of which rings was again to be composed of separate segments, as shown in the front view of the lens in *fig.* 1133. This lens is composed of one central lens A B C D, corresponding with its section D E in *fig.* 1133; of a middle ring G E L I, corresponding to C D E F, and consisting of 4 segments; and another ring N P R T, corresponding to A C F B, and consisting of 8 segments. The preceding construction obviously puts it in our power to execute those lenses to which I have given the name of *polyzonal lenses*, of pure flint glass free from veins; but it possesses another great advantage, namely, that of enabling us to correct very nearly the spherical aberration by making the foci of each zone coincide." — *Brewster.*

1132

1133



This description will enable the reader to understand the system which has been adopted by Fresnel and carried out by the French government, and by our own commissioners of lights.

In the fixed dioptric light of Fresnel, the flame is placed in the centre of the apparatus, and within a cylindric reflector of glass, of a vertical refracting power, the breadth and height of a strip of light emitted by it being dependent upon the size of the flame and the height of the reflector itself; above and below is placed a series of reflecting prismatic rings or zones for collecting the upper and lower divergent rays, which, falling upon the inner side of the zone are refracted, pass through the second side where they suffer total reflection, and, passing out on the outer side of the zone, are again refracted. The effect of these zones is to lengthen the vertical strip of

light, the size of which is dependent upon the breadth of the flame and the height of the apparatus.

In Fresnel's revolving lighthouse, a large flame is placed in the centre of a revolving frame which carries a number of lenses on a large scale and of various curvatures for the avoidance of spherical aberration. With the view of collecting the divergent rays above the flame, an arrangement of lenses and silvered mirrors is placed immediately over it. By this compound arrangement the simply revolving character of the apparatus is destroyed, as, in addition to the revolving flash, a vertical and fixed light is at all times seen, added to which a great loss of light must be sustained by the loss of metallic reflectors. In 1851, Messrs. Wilkins and Letourneau, exhibited a catadioptric apparatus of great utility. It was thus described by the exhibitors : —

The first improvement has special reference to the light, and produces a considerable increase in its power, whilst the simplicity of the optical arrangements is also regarded. It consists, firstly, in completely dispensing with the movable central cylindrical lenses; secondly, it replaces these by a single revolving cylinder composed of four annular lenses and four lenses of a fixed light introduced between them; but the number of each varying according to the succession of flashes to be produced in the period of revolution.

The second improvement, of which already some applications that have been made serve to show the importance, consists in a new method of arranging the revolving parts, experience having shown that the arrangements at present in use are very faulty. A short time is sufficient for the action of the friction rollers, revolving on two parallel planes, to produce by a succession of cuttings a sufficiently deep groove to destroy the regularity of the rotatory movement. To obviate this great inconvenience the friction rollers are so placed and fitted, on an iron axis with regulating screws and traversing between two bevelled surfaces, that when an indentation is made in one place they can be adjusted to another part of the plates which is not so worn.

The third improvement produces the result of an increase of the power of the flashes in revolving lighthouse apparatus to double what has been obtained hitherto. By means of lenses of vertical prisms placed in the prolongation of the central annular lenses, the divergent rays emerging from the catadioptric zone are brought into a straight line, and a coincidence of the three lenses is obtained.

The whole of the prisms, lenses, and zones are mounted with strength and simplicity, accurately ground and polished to the correct curves according to their respective positions, so as to properly develope this beautiful system of Fresnel. The glass of which they are composed should be of the clearest crystal colour, and free from that green hue which so materially reduces the power of the light, and is considered objectionable for apparatus of this kind. The lamp by which the apparatus is to be lighted consists of a concentric burner with four circular wicks attached to a lamp of simple construction, the oil being forced up to the burner by atmospheric pressure only, so that there are no delicate pumps or machinery to become deranged.

Stevenson's revolving lighthouse.—This apparatus consists of two parts. The principal part is a right octagonal hollow prism composed of eight large lenses, which throw out a powerful beam of light whenever the axis of a single lens comes in the line between the observer and the focus. This occurs once in a minute, as the frame which bears the lens revolves in eight minutes on the rollers placed beneath. The subsidiary parts consist of eight pyramidal lenses inclined at an angle of 30° to the horizon, and forming together a hollow truncated cone, which rests above the flame like a cap. Above these smaller lenses (which can only be seen by looking from below) are placed eight plane mirrors, whose surfaces being inclined to the horizon at 50° in the direction opposite to that of the pyramidal lenses, finally cause all the light made parallel by the refraction of these lenses to leave the mirror in a horizontal direction. The only object of this part is to turn to useful account, by prolonging the duration of the flash, that part of the light which would otherwise escape into the atmosphere above the main lenses. This is effected by giving to the upper lenses a slight horizontal divergence from the vertical plane of the principal lenses. Below are five tires of totally reflecting prisms, which intercept the light that passes below the great lenses, and by means of two reflexions and an intermediate refraction project them in the shape of a flat ring to the horizon.

Stevenson's fixed dioptric apparatus of the first order (same as that at the Isle of May, with various improvements). The principal part consists of a cylindric belt of glass which surrounds the flame in the centre, and by its action refracts the light in a *vertical* direction upward and downward, so as to be parallel with the focal plane of the system. In this way it throws out a flat ring of light equally intense in every direction. To near observers, this action presents a narrow vertical band of light,

depending for its breadth on the extent of the horizontal angle embraced by the eye. This arrangement therefore fulfils all the conditions of a fixed light, and surpasses in effect any arrangement of parabolic reflectors. In order to save the light which would be lost in passing above and below the cylindrical belt, curved mirrors with their common focus in the lamp were formerly used; but by the present engineer, the adaptation of *catadioptric* zones to this part of the apparatus was, after much labour, successfully carried out. These zones are triangular, and act by *total* reflexion, the inner face *refracting*, the second *totally reflecting*, and the third or outer face, a second time *refracting*, so as to cause the light to emerge *horizontally*. The apparatus has received many smaller changes by the introduction of a new mode of grouping the various parts of the frame work, by which the passage of the light is less obscured in every azimuth.

Mechanical lamps of four wicks, are used in these lighthouses; in these the oil is kept continually overflowing by means of pumps which raise it from the cistern below; thus the rapid carbonisation of the wicks, which would be caused by the great heat, is avoided. The flames of the lamp reach their best effect in three hours after lighting, *i. e.* after the whole of the oil in the cistern, by passing and repassing over the wicks repeatedly, has reached its maximum temperature. After this the lamp often burns 14 hours without sensible diminution of the light, and then rapidly falls. The height varies from 16 to 20 times that of the argand flame of an inch in diameter; and the quantity of oil consumed by it is greater nearly in the same proportion.

In *Stevenson's ordinary parabolic reflector*, rendered *holophotal* (where the entire light is parallelised) by a portion of a catadioptric annular lens, the back part of the parabolic conoid is cut off, and a portion of a spherical mirror substituted, so as to send the rays again through the flame; while his *holophotal catadioptric annular lens apparatus* is a combination of a hemispherical mirror and a lens having totally-reflecting zones; the peculiarity of this arrangement is, that the catadioptric zones, instead of transmitting the light in parallel horizontal plates, as in Fresnel's apparatus, produces, as it were, an extension of the lenticular or quaquaversal action of the central lens by assembling the light around its axis in the form of concentric hollow cylinders.

Mr. Chance, of Birmingham, constructed a lighthouse which may be regarded as Fresnel's revolving light rendered holophotal. This arrangement was divided into three compartments, the upper and lower of which were composed respectively of thirteen and six catadioptric zones which produce the vertical strip of light extending the whole length of the apparatus, and is similar to Fresnel's dioptric light. The central or catoptric compartment consisted of eight lenses of three feet focal length, each of which was the centre of a series of eleven concentric prismatic rings, designed to produce the same refractive effect as a solid lens of equal size. These compound lenses were mounted upon a revolving frame and transmitted horizontal flashes of light as they successively rotated. The motion was communicated to the frame by a clock movement, and performs one revolution in four minutes; consequently, as there are eight lenses, a flash of light is transmitted every thirty seconds to the horizon.

LIGNEOUS MATTER is vegetable fibre. See FIBRE VEGETABLE.

LIGNITE. Under BROWN COAL, BOGHEAD COAL, and COAL, the characteristics of lignite have already received attention, therefore little further need be said. The term lignite should be confined to fossil wood, or, still more correctly to wood which has undergone one of the changes leading *towards* the production of coal. If wood is buried in moist earth there is the production of carbonic acid from the elements of the wood, and the wood is changed into either lignite or brown coal. Lignite and coal differ chemically from each other. Lignite yields by dry distillation acetic acid and acetate of ammonia, whereas coal produces only an ammoniacal liquor. (*Kremers.*) Woody fibre gives rise to acetic acid; therefore, lignite must still contain undecomposed woody fibre. The following table gives the composition of several well known lignites.

	Carbon.	Hydrogen.	Oxygen and Nitrogen.	Earthy matter.	Chemist.
From Uttweiler - -	77·9	2·6	19·5	1	Karsten
„ Hungary - -	67·3	4·3	- -	0·8	Nendtwich
„ the Rhone - -	72·2	4·9	20·1	1·8	Regnault
„ Meissner - -	68·6	5·9	19 0	2·3	Gräger
„ Bovey Heathfield-	67·9	5·8	24·8	- -	Vaux

In Prussia, Austria, and many other parts of the continent, ligaite forms a very

important product, being largely employed for domestic and for manufacturing purposes. In this country, with the single exception of the Bovey Heathfield formation, which is used in the adjoining pottery, lignite is not employed.

LIGNUM-VITÆ, or *Guaiacum* (*Guaiacum officinale* and *G. sanctum*), a very hard and heavy wood. The fibrous structure of this wood is very remarkable; the fibres cross each other sometimes as obliquely as at an angle of 30 degrees with the axis, as if one group of the annual layers wound to the right the next to the left and so on, with any exactitude. The wood can hardly be split, it is therefore divided by the saw. Lignum-vitæ is much used in machinery for rollers, presses, mills, &c., and for pestles and mortars, sheers for ship's blocks, skittle balls, and a great variety of other works requiring hardness and strength.

The gum guaiacum of the apothecary is extracted from this wood.

LILAC DYE. See CALICO-PRINTING, DYEING, AND ANILINE.

LIME. *Quicklime*, an *Oxide of Calcium*. This useful substance is prepared by exposing the native carbonate of lime to heat, by which the carbonic acid is expelled.

This operation is performed in a manner more or less perfect, by burning calcareous stones in kilns or furnaces.

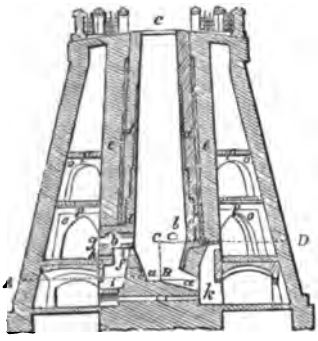
Limestone used to be calcined in a very rude kiln, formed by inclosing a circular space of 10 or 15 feet diameter, by rude stone walls 4 or 5 feet high, and filling the cylindrical cavity with alternate layers of turf or coal and limestone broken into moderate pieces. A bed of brushwood was usually placed at the bottom, to facilitate the kindling of the kiln. Whenever the combustion was fairly commenced, the top, piled into a conical form, was covered in with sods, to render the calcination slow and regular. This method being found relatively inconvenient and ineffectual, was succeeded by a permanent kiln built of stones or brickwork, in the shape of a truncated cone with the narrow end undermost, and closed at bottom by an iron grate. Into this kiln, the fuel and limestone were introduced at the top in alternate layers, beginning of course with the former; and the charge was either allowed to burn out, when the layer was altogether removed at a door near the bottom, or the kiln was successively fed with fresh materials, in alternate beds, as the former supply sunk down by the calcination, while the thoroughly burnt lime at the bottom was successively raked out by a side door immediately above the grate. The interior of the lime kiln has been changed of late years from the conical to the elliptical form, and probably the best is that of an egg placed with its narrow end undermost, and truncated both above and below; the ground plot or bottom of the kiln being compressed so as to give an elliptical section, with an *eye* or draft-hole towards each end of that ellipse. A kiln thus arched in above gives a reverberatory heat to the upper materials, and also favours their falling freely down in proportion as the finished lime is raked out below; advantages which the conical form does not afford. The size of the draft-holes for extracting the quicklime, should be proportionate to the size of the kiln, in order to admit a sufficient current of air to ascend with the smoke and flame, which is found to facilitate the extrication of the carbonic acid. The kilns are called *perpetual*, because the operation is carried on continuously as long as the building lasts; and *draw-kilns*, from the mode of discharging them by raking out the lime into carts placed against the draft-holes. Three bushels of calcined limestone, or lime-shells, are produced on an average for every bushel of coals consumed. Such kilns should be built up against the face of a cliff, so that easy access may be gained to the mouth for charging, by making a sloping cart road to the top of the bank.

Figs. 1134, 1135, 1136, 1137 represent the *lime-kiln* of Rüdersdorf near Berlin, upon the continuous plan, excellently constructed for economising fuel. It is triple, and yields a threefold product. *Fig.* 1136 is a view of it as seen from above; *fig.* 1137, the elevation and general appearance of one side; *fig.* 1134, a vertical section, and *fig.* 1135, the ground plan in the line A B C D of *fig.* 1134. The inner shaft *fig.* 1135, has the form of two truncated cones, with their larger circular ends applied to each other; it has the greatest width at the level of the fire-door *b*, where it is 8 feet in diameter; it is narrower below, at the discharge door, and at the top orifice, where it is about 6 feet in diameter. The interior wall *d*, of the upper shaft is built with hewn stones to the height of 38 feet, and below that for 25 feet, with fire-bricks d' d', laid stepwise. This inner wall is surrounded with a mantle *e*, of limestone, but between the two there is a small vacant space of a few inches filled with ashes, in order to allow of the expansion of the interior with heat taking place without shattering the mass of the building.

The fire-grate, *b*, consists of fire-tiles, which at the middle, where the single pieces press together, lie upon an arched support *f*. The fire-door is also arched, and is secured by fire-tiles. *g* is the iron door in front of that orifice. The tiles which form the grate have 3 or 4 slits of an inch wide for admitting the air, which enters through the canal *h*.

The under part of the shaft from the fire to the hearth is 7 feet, and the outer enclosing wall is constructed of limestone, the lining being of fire-bricks. Here are the ash-

1134



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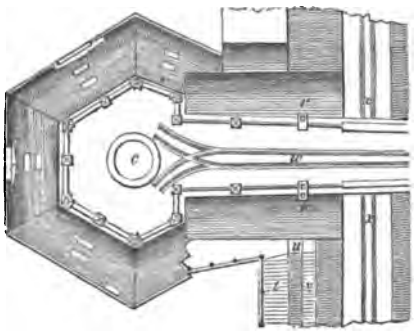

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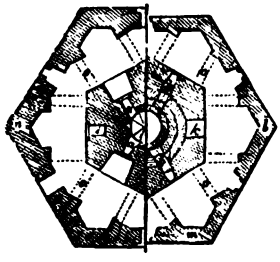

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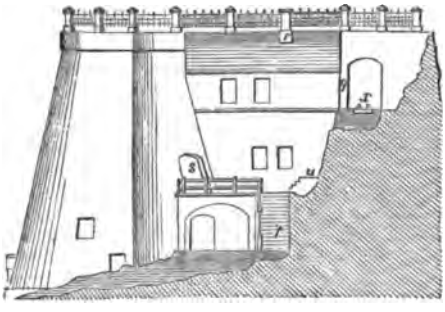

pit *i*, the discharge outlet *a*, and the canal *k*, in front of the outlet. Each ash-pit is shut with an iron door, which is opened only when the space *i* becomes filled with ashes. These indeed are allowed to remain till they get cool enough to be removed without inconvenience.

The discharge outlets are also furnished with iron doors, which are opened only for taking out the lime, and are carefully luted with loam during the burning. The outer walls *l m n* of the kiln, are not essentially necessary, but convenient, because they afford room for the lime to lie in the lower floor, and the fuel in the second. The several stories are formed of groined arches *o*, and platforms *p*, covered over with limestone slabs. In the third and fourth stories the workmen lodge at night. See *fig.* 1137. Some enter their apartments by the upper door *q*; others by the lower door *s*. *r* is one of the chimneys for the several fireplaces of the workmen. *t*, *u*, *v* are stairs.

As the limestone is introduced at top, the mouth of the kiln is surrounded with a strong iron balustrade to prevent the danger of the people tumbling in. The platform is laid with rails *w*, for the waggons of limestone, drawn by horses, to run upon. *x* is another railway, leading to another kiln. Such kilns are named after the number of their fire-doors, single, twofold, threefold, fourfold, &c.; from three to five being the most usual. The outer form of the kiln also is determined by the number of the furnaces; being a truncated pyramid of equal sides; and in the middle of each alternate side there is a fireplace, and a discharge outlet. A cubic foot of limestone requires for burning, one and five-twelfths of a cubic foot of wood, and one and a half of turf.

When the kiln is to be set in action, it is filled with rough limestones, to the height C D, or to the level of the firing; a wood fire is kindled in *a*, and kept up till the lime is calcined. Upon this mass of quicklime, a fresh quantity of limestones is introduced, not thrown in at the mouth, but let down in buckets, till the kiln is quite full; while over the top a cone of limestones is piled up, about 4 feet high. A turf-fire is now kindled in the furnaces *b*. Whenever the upper stones are well calcined, the lime

under the fire-level is taken out, the superior column falls in, a new cone is piled up, and the process goes on thus without interruption, and without the necessity of once putting a fire into *a*; for in the space C B, the lime must be always well calcined. The discharge of lime takes place every 12 hours, and it amounts at each time in a three-fold kiln, to from 20 to 24 Prussian *tonnes* of 6 imperial bushels each; or to 130 bushels imperial upon the average. It is found by experience that fresh-broken limestone, which contains a little moisture, calcines more readily than what has been dried by exposure for some time to the air; in consequence of the vapour of water promoting the escape of the carbonic acid gas; a fact well exemplified in distilling essential oils, as oil of turpentine and naphtha, which come over with the steam of water at upwards of 100° Fahr. below their natural term of ebullition. Six bushels of Rüdersdorf quicklime weigh from 280 to 306 pounds.

Anhydrous lime, or, as it is commonly called "*quicklime*," is an amorphous solid, varying much in coherence, according to the kind of rock from which it is obtained; its specific gravity varies from 2·3 to 3. Lime is one of the most infusible bodies which we possess; it resists the highest heats of our furnaces.

When exposed to air, quicklime rapidly absorbs water and crumbles into a powder, commonly known as *slaked lime*, which is a *hydrate of lime*.

Hydrate of lime when exposed to the air absorbs carbonic acid, and after long exposure it is converted into a mixture of carbonate of lime and hydrate of lime in single equivalents. Hydrate of lime is but slightly soluble in water, 729 to 733 parts of that fluid dissolving only 1 part of the lime at ordinary temperatures.

Hydrate of lime is applied to numerous purposes in the arts and manufactures. It is chiefly employed in the preparation of mortar for building purposes. See MORTAR.

The pure limes, prepared from the carbonates of lime, form an imperfect mortar suitable only for dry situations. In damp buildings or in wet situations they never *set* (as the process of hardening is technically termed), but always remain in a pulpy state. General Pasley says, "The unfitness of pure lime for the purposes of hydraulic architecture has been proved by several striking circumstances that have come under my personal observation, of which I shall only mention a few. First, a great portion of the boundary wall of Rochester Castle having been completely undermined, nearly throughout its whole thickness, which was considerable, whilst the upper part of the same wall was left standing, I had always ascribed this remarkable breach to violence, considering it as having been the act of persons intending to destroy the wall for the sake of the stone; but on examining it more accurately after I had begun to study the subject of limes and cements, I observed that the whole of the breached part was washed by the Medway at high water, and that all the mortar of a small portion of the back part of the foot of the wall still left standing was quite soft, but that towards the ordinary high water level it became a little harder, and above that level it was perfectly sound. I observed the same process at the outer wall of Cockham Wood Fort, on the left bank of the Medway below Chatham, of which the upper part was standing, whilst the lower part of it had been gradually ruined by the action of the river at high water destroying the mortar."

Obervations on limes, calcareous cements, &c. — The peculiar conditions necessary to insure a good and useful mortar for building purposes, and, the peculiarities of the hydraulic mortars or cements, will be treated of under MORTAR, which see.

LIMESTONE. (*Calcaire*, Fr; *Kalkstein*, Germ.) A great variety of rocks contain a sufficient quantity of lime in combination to be called limestones.

Chalk is an earthy massive opaque variety, usually soft and without lustre, and may be regarded as a tolerably pure carbonate of lime. Carbonate of lime dissolves in 1000 parts of water charged with carbonic acid. (*Bischof.*) Fresenius states that it dissolves in 8834 parts of boiling water and in 10,601 parts of water at ordinary temperatures.

Carbonate of lime is found in nature more or less pure, both crystallised *perfectly*, as in calcspar and aragonite imperfectly; as in granular limestone; and in compact masses, as in common limestone, chalk, &c.

Stalactitic carbonate of lime, frequently called concretionary limestone, is formed by the infiltration of water through rocks containing lime, which is dissolved out, and as it slowly percolates the rocks into cavernous openings, the water parts with its carbonate of lime, which is deposited in zones more or less undulated, which have a fibrous structure from the crystalline character of the concretionary lime. The long fibrous pieces called stalactites show those fibres very beautifully. The stratiform masses called stalagmites exhibit a similar structure, varied only by the conditions under which they are formed. A very remarkable stalagmitic limestone found in Egypt is known as oriental alabaster.

True *Alabaster* is a sulphate of lime (see ALABASTER), but the stalagmitic carbonate is not unfrequently called by this name.

Incrusting concretionary limestones differ but little from the above. They are deposits

from calcareous springs which are common in some parts of Derbyshire, Yorkshire, and other places. It is a common practice to place vegetable substances in those springs; they then become incrusted with carbonate of lime, and are sold as petrifactions, which they are not. In volcanic districts many very remarkable springs of this character exist. One of the most remarkable is at the baths of San Filippo in Tuscany, where the water flows in almost a boiling state; carbonate of lime here appears to be held in solution by sulphuretted hydrogen, which flies off when the water issues to day. Dr. Vegny has taken advantage of this property of the spring to obtain basso-relievo figures of great whiteness and solidity by occasioning the lime to deposit in sulphur moulds.

Agaric mineral, Spongy limestone, Rock milk, is found at the bottom of and about lakes whose waters are impregnated with lime. The *calcareous tufa* of Derbyshire is of this character; it may be studied in every stage of formation.

Travertine, which served to construct most of the monuments in ancient Rome, appears to have been formed by the deposits of the Anio and the Solfatara of Tivoli. The temples of Pæstum, which are of extreme antiquity, have been built with a *travertine*, formed by the waters which still flow in this territory.

Compact limestone has a compact texture, usually an even surface of fracture, and dull shades of colour.

Granular limestone includes common statuary and architectural marble, and has a texture something like loaf-sugar. (See MARBLE.) Under those two heads are grouped a great number of varieties.

Oolite or *roe stone* consists of spherical grains of various sizes, from a millet seed to a pea or even an egg.

Coarse grained limestone. Coarse lias has been referred to this head.

Marly limestone. Lake and fresh-water limestone formation, texture fine grained, more or less dense; apt to crumble down in the air; colour white or pale yellow; fracture rough grained, somewhat conchoidal; somewhat tenacious. Texture occasionally cavernous, with cylindrical winding cavities. This true limestone must not be confounded with lime marl, which is composed of calcareous matter and clay.

Siliceous limestone. A combination of silica and carbonate of lime, varying very much in the proportions and sometimes passing from *cherty limestone* into *chert*. It scratches steel, and leaves a siliceous residuum after the action of muriatic acid.

Stinkstone or Swinestone. A carbonate of lime combined with sulphur and organic matter. It emits the smell of sulphuretted hydrogen by a blow or by friction. It occurs at Assynt, in Sutherlandshire, in Derbyshire, and some parts of Ireland.

Bituminous limestone. Limestone containing various hydrocarbon compounds, diffusing by the action of fire a bituminous odour, and becoming white when burnt.

Limestones of whatsoever kind may be referred to deposition effected by chemical change. The immense lapse of time required to form the great limestone ranges of this country can scarcely be estimated. Professor Phillips has the following remarks on this: —

"It is certain that while the sandstones, shales, coals, and thin oolitic limestones of the North York moors were deposited upon the lias, a deposit almost wholly calcareous was occasioned near Bath. The whole time consumed was the same in each locality. We may, therefore, perhaps infer the comparative rate of deposition of the oolite and the sandstones. The total thickness of the mass in Yorkshire is about 750 feet, of which about 20 may be called limestone; of that near Bath 480, of which nearly half is sand and clay with calcareous matter interspersed. Hence we have the proportion of three feet of sandstone deposited in the same time as one of limestone. Another instance is afforded by comparing the sections of the lower carboniferous limestone in Derbyshire and in Tynedale. In the former tract we may take 750 feet as the thickness of limestone, with no admixture of sands or clays; in the latter; the contemporaneous strata are at least 1,750 feet thick, and contain 367 feet of limestone, and 1,283 feet of sands and clays, &c.; consequently, 383 of limestone correspond in time to 1,283 of sand, clays, and coal, or 1 to 3 3."

The formation of limestone under different circumstances is an interesting study. Some of our great limestone formations indicate a marine, while others very clearly show a fresh water origin. Mr. Jukes, in his *Student's Manual of Geology*, says: "The marine depositions of carbonate of lime now taking place are best studied in coral reefs. In almost all tropical seas incrusting patches or small banks of living coral are to be found along the shores, wherever they consist of hard rock and the water is quite clear. In the Indian and Pacific Oceans, however, far away from any land, huge masses of coral rock rise up from vast and unknown depths, just to the level of low water. These masses are often unbroken for many miles in length and breadth; and groups of such masses, separated by small intervals, occur over spaces sometimes 400 or 500 miles long by 50 or 60 in width. The barrier reef along the

north-east coast of Australia is composed of a chain of such masses, and is more than 1000 miles long, from 10 to 90 miles in width, and rises at its seaward edge from depths which in some places certainly exceed 1800 feet. These reef masses consist of living corals only at their upper and outer surface, all the interior is composed of dead corals and shells, either whole or in fragments, and the calcareous portions of other marine animals. The interstices of the mass are filled up and compacted together by calcareous sand and mud, derived from the waste and débris, the wear and tear of the corals and shells, and by countless myriads of minute organisms, mostly calcareous also. The surface of a reef when exposed at low water is composed of solid looking stone, which is often capable of being split up and lifted in slabs, bearing no small resemblance to some of our oldest limestones. . . . . Guided by these facts and observations we may form tolerably accurate notions of the mode of origin of all our marine limestones, and attribute to them an organic-chemical origin, taking into account, at the same time, how easily they may have been subsequently altered in texture by the metamorphic action either of water or heat." Dr. Lyon Playfair suggests two additional modes by which a chemical precipitation of carbonate of lime might in some places be formed on the bottom of the seas. He says most rivers contain small quantities of silicate of potash; and when this is carried into the sea, some of the carbonic acid contained therein may unite with the potash, thus rendering possible a precipitation of carbonate of lime in a solid form, and also of silica. Marine vegetables also, like terrestrial vegetation, require carbonic acid, and, by extracting it from sea water, may reduce the amount in particular localities below that which is necessary to keep all the carbonate of lime in a fluid state, and thus render a solid precipitation of that substance possible.—*De la Beche.*

"Limestones," says Mr. Jukes, "may be hard or soft, compact, concretionary, or crystalline, consisting of pure carbonate of lime or containing silica, alumina, iron, &c., either as mechanical admixtures or as chemical deposits along with it. Different varieties of limestone occur in different localities, both geographical and geological, peculiar forms of it being often confined to particular geological formations over wide areas, so that it is much more frequently possible to say what geological formation a specimen was derived from, by the examination of its lithological characters, in the case of limestone than in that of any other rock. *Compact limestone* is a hard smooth fine-grained rock, generally bluish-grey, but sometimes yellow, black, red, white or mottled. It has either a dull earthy fracture or a sharp splintery and conchoidal one. It will frequently take a polish, and when the colour is a pleasing one is used as an ornamental marble. *Crystalline limestone* may be either coarse or fine-grained, varying from a rough granular rock of various colours to a pure white fine-grained one, resembling loaf-sugar in texture. This latter variety is sometimes called *saccharine*, sometimes *statuary marble.*"

Oolitic limestone includes Bath stone, Portland stone, and Caen stone.

Pisolite is a variety of oolite, in which the concretions become as large as peas.

Nummulitic limestone, *Clymenia*, *Crinoidal* limestones are so called from the fossils which the rock contains.

Shell limestone or *muschelkalk* has its name in the same way from its composition.

Cipolino is a granular limestone containing mica.

Majolica, a white and compact limestone.

Scaglia, a red limestone in the Alps. For the three last see MARBLE.

LIMESTONE, MAGNESIAN, see DOLOMITE (*Dolomie*, Fr.; *Bitterkalk*, *Talkspath*, Germ.), is a mineral which crystallises in the rhombohedral system. Spec. grav. 2·88; scratches calc-spar; does not fall spontaneously into powder when calcined, as common limestone does. It consists of 1 prime equivalent of carbonate of lime = 50, associated with 1 of carbonate of magnesia = 42.

Massive magnesian limestone, is yellowish-brown, cream-yellow, and yellowish-grey; brittle. It dissolves slowly and with feeble effervescence in dilute muriatic acid; whence it is called *Calcaire lent dolomie*, by the French mineralogists. Specific gravity 2·6 to 2·7.

Near Sunderland, it is found in flexible slabs. The principal range of hills composing this geological formation in England, extends from Sunderland on the north-east coast to Nottingham, and its beds are described as being about 300 feet thick on the east of the coal field in Derbyshire, which is near its southern extremity.—H. W. B.

LIME TREE (*Tilia Europea*). The well-known linden tree, common to all Europe. The wood is very light-coloured, fine and close in the grain, and when properly seasoned, not liable to warp. It is much used in the manufacture of piano fortes and harps. It is made into cutting boards for curriers, shoemakers, &c., as it does not turn the knife in any direction of the grain, nor injure the edge.

Lime tree wood is especially useful for carving, from its even texture and freedom

from knots. The beautiful works of Gibbons at Hampton Court, at Windsor, and at Chatsworth, are executed in lime tree wood.

The no less beautiful works of our celebrated living wood carver, Rogers, are executed in this wood.

LIMOGE WARE. See POTTERY.

LIMONITE. A name for several varieties of iron ore, such as the brown hæmatite and bog iron ore. There is much difficulty in distinguishing the various kinds of iron ore, they shade so gradually one into the other; but it is clearly a very unscientific mode of proceeding to group things unlike each other under a common name.

LINSEYS, sometimes called linsey-woolsey; being a combination of flax and wool, which are woven into coarse cloth, usually employed to clothe those who are entirely dependent on public charity.

LINEN. See FLAX, and TEXTILE FABRICS.

LINEN *distinguished from cotton.* Cotton may be distinguished from linen or flax by immersing the former, well washed and dried, for about a minute in strong sulphuric acid. It is then to be withdrawn and washed with water containing a little alkali. The cotton will dissolve as a gummy mass, while the linen will retain its thready texture.

The manufacture of linens is carried on extensively in the north of Ireland, and on the continent in Bohemia, Moravia, Silesia, and Galicia. Of the entire production, independent of the Irish linen, about five-twelfths are brought into the market, and of this quantity the bulk must be of domestic manufacture, since few great linen manufactories exist in Austria. Within the Austrian dominions, among the linen fabrics, table-cloths and napkins, veils, cambrics, dimities, twills, and drills are important articles. In the next rank we must place the manufacture of thread, especially in Bohemia, Moravia, and Lombardy. The tape manufacture is of less consequence; and as to the business of dyeing and printing, that has been almost entirely absorbed by the cotton manufacture, and is now in requisition for thread and handkerchiefs only.

As the loss resulting from the processes of weaving, bleaching, &c. is estimated at about 10 per cent. the net aggregate of these manufactures of linen, thread, &c., may be assumed at, say, 1,037,000 cwt.; of which quantity about 450,000 cwt. come into the market, the rest being absorbed by domestic consumption. Since, upon an average of the five years from 1843 to 1847, there appear to have been imported from abroad only 242 cwt. whereas the average of exports for the same period shows 42,609 cwt., it follows that there remained for home consumption about 1,000,000 cwt. Thus, on a population of 38,000,000 of persons, about 2¾ lbs. would fall to the share of each; but this estimate falls much below the truth, when we consider that the national costume in Hungary and Galicia requires more than double the quantity we have allowed for. In fact the crop of flax is estimated to be 10 per cent. higher than is given in the official reports; but the consumption of even 3 lbs. per head, which would thus result, is yet smaller than in reality it must be. In the imperial army of Austria the quantity used up annually by each man averages more than 7 lbs.

In the above statistics of the manufacture of linen goods no allowance has been made for the extensive production of rope work and the like.

From the article FLAX, reference has been made to this article for available information in the statistics of the production of the raw material and of the finished article in this country. The following ample tables will fully set forth the value of this important manufacture.

After the information already conveyed to the reader in the article FLAX, what has been said with regard to COTTON MANUFACTURE, and the additional matter in the article TEXTILE FABRICS, it does not appear necessary to say anything more on the subject of linen manufacture.

Imports of Flax in 1857.

Flax dressed: —

From	Cwts.	£
Russia	40	112
Prussia	36	101
Holland	2,374	6,635
Belgium	26	72
Egypt	839	1,791
Other parts	560	1,541
	3,875	£10,252

Tow and codilla of flax: —

From	Cwts.	£
Russia	193,195	284,996
Prussia	10,359	15,110
Hanover	4,682	6,685
Hanse Towns	6,715	9,448
Holland	23,736	33,324
Belgium	1,386	1,888
Other parts	1,910	2,637
	241,986	£354,088

Rough and undressed: —

From	Cwts.	£
Russia	1,081,657	1,924,707
Prussia	263,177	475,154
Holland	120,374	320,928
Belgium	120,913	353,599
France	24,253	70,597
Egypt	6,099	7,463
Other parts	3,916	7,979
	1,620,389	£3,160,427

Imports of Linen in 1857.

Linen yarn: —

From	Cwts.	Computed real Value.
Russia	2,487	£17,131
Other parts	43	291
	2,530	£17,422

Linen manufactures: —

Cambric handkerchiefs, hemmed or hemstitched, not trimmed: —

From	Number.	Computed real Value.
France	36,379	£5,002
Other parts	131	18
	36,510	£5,020

Cambrics and lawns, commonly called French lawns, plain: —

From	Square Yards.	Computed real Value.
Belgium	260	£650
France	18,718	4,679
	21,318	£5,329

Bordered handkerchiefs: —

From	Square Yards.	Computed real Value.
Belgium	8,508	£1,382
France	115,871	18,829
Other parts	700	114
	125,079	£20,325

Entered at Value.

Lawns not French: —

From	£
Egypt	147
China	623
Other parts	87
	£857

Damask and damask diaper: —

From	Square Yards.	£
Hanse Towns	12,185	1,823
Holland	1,958	226
France	3,025	227
	17,168	£2,276

Entered at Value.

Sails:—

From	£	From	£
Russia	564	United States	1,180
Norway	212	Australia	360
Hanse Towns	241	Other parts	944
Holland	1,669		£5 559
Belgium	389		

Plain linen and diaper unenumerated:—

From	£	From	£
Hanse Towns	58	Other parts	21
Holland	35		£264
Belgium	150		

Not separately specified, wholly or partially made up:—

From	£	From	£
Russia	391	British East Indies	193
Hanse Towns	2,031	Other parts	292
Holland	1,381		£11,557
Belgium	385		
France	6,882.		

Ditto, not made up:—

From	£	From	£
Russia	19,297	United States	581
Hanse Towns	5,832	Malta	945
Holland	1,548	Australia	2,358
Belgium	9,864	Other parts	1,667
France	1,536		£44,348
Turkey Proper	720		

Exports of Linen, &c. in 1857.

Linen yarn:—

To	Lbs.	Value.
Russia, northern ports	83,047	£6,578
Denmark	303,394	13,636
Prussia	318,239	23,043
Hanover	1,296,836	86,306
Hanse Towns	9,142,759	522,246
Holland	4,405,029	250,784
Belgium	2,072,562	117,268
France	528,980	88,507
Spain and Canaries	7,493,534	389,474
Sardinia	933,151	40,638
Tuscany	535,071	24,538
Two Sicilies	298,817	18,794
Austrian territories	73,438	4,013
Turkey	133,866	5,822
United States	69,867	2,454
Gibraltar	1,042,134	45,363
Other countries	178,239	12,250
	28,908,963	£1,651,714

Linen manufactures:—

White and plain:—

To	Yards.	£
Russia, northern ports	310,013	16,339
Norway	117,326	5,512
Denmark	582,910	16,873
Prussia	125,595	6,085
Hanover	144,957	7,923
Hanse Towns	5,354.685	182,897
Holland	744,525	24,030
Belgium	188,864	7,872
France	1,105,156	70,910
Portugal, &c.	1,344,823	32,453

White and plain (*continued*) —

To	Yards.	£
Spain, &c.	1,677,439	80,052
Sardinia	740,085	31,693
Tuscany	744,693	28,598
Papal States	218,354	8,964
Two Sicilies	773,085	36,128
Austrian territories	431,916	17,189
Turkey	400,632	15,197
Egypt	189,655	7,249
Philippine Islands	407,098	10,798
China	519,128	8,656
South Sea Islands	673,101	11,138
Cuba	10,829,176	375,583
Porto Rico	313,437	7,390
St. Thomas	6,018,485	147,164
Haiti	2,688,357	70,774
United States	42,943,492	1,290,890
Mexico	1,815,399	68,764
Central America	245,602	7,130
New Grenada	1,796,596	42,971
Venezuela	3,653,563	80,046
Brazil	11,540,439	299,340
Uruguay	416,055	10,758
Buenos Ayres	963,332	29,965
Chili	2,755,475	75,584
Peru	2,254,011	72,638
Channel Islands	245,980	12,924
Gibraltar	585,730	23,964
Malta	306,684	10,770
British possessions in South Africa	825,726	26,241
Mauritius	112,976	3,675
British East Indies	1,332,502	53,063
Hong Kong	140,874	4,567
Australia	3,296,744	105,939
British North America	2,256,505	66,408
British West Indian islands, &c.	4,818,537	105,759
Honduras British settlements	184,984	4,532
Other countries	709,274	20,390
	119,847,975	£3,643,785

Checked or striped: —

To	Yards.	£
United States	76,069	1,865
British possessions in South Africa	20,652	328
British West Indies, &c.	47,400	1,106
Other countries	35,154	1,066
	179,275	£4,365

Printed, stained, or dyed: —

To	Yards.	£
Hanse Towns	77,907	1,853
France	22,412	2,904
Cuba	1,930,204	70,011
Porto Rico	211,548	4,300
St. Thomas	483,046	8,480
United States	1,957,645	55,111
New Grenada	115,670	3,014
Brazil	337,989	15,353
Australia	61,712	1,500
British North America	230,118	5,793
British West Indian Isles	452,946	8,870
Other countries	246,011	7,030
	6,127,208	£184,619

Cambric and lawn:—

To	Yards.	£
Java	15,000	1,691
Cuba	84,184	4,085
United States	1,183,768	51,110
New Grenada	91,596	2,446
Brazil	34,190	2,266
Buenos Ayres	7,225	1,306
British East Indies	17,215	913
Australia	44,583	2,718
British West Indies	20,238	766
Other countries	84,124	5,381
	1,582,123	£72,682

Damask and diaper:—

To	Yards.	£
Hanse Towns	51,966	3,301
United States	454,613	24,005
Australia	31,113	2,184
British North America	10,970	581
Other countries	54,427	4,757
	603,089	£34,828

	Yards.	£
Sail cloth, total exports	5,442,327	234,845
Sails ditto	-	7,667
Ticking ditto	57,596	1,630

Lace of thread:—

To	Yards.	£
United States	23,365	971
Brazil	6,000	124
Channel Islands	18,000	450
Other countries	25,532	747
	72,897	£2,292

Hosiery, tapes, and small wares:—

To	£
Hanse Towns	844
United States	1,390
Peru	1,374
Other countries	4,421
	£8,029

Thread for sewing:—

To	Lbs.	£
Russia, northern ports	23,371	2,180
Norway	61,383	4,275
Denmark	24,753	2,575
Hanover	88,116	10,438
Hanse Towns	864,220	94,332
Holland	35,674	3,258
Belgium	31,300	3,405
Austrian territories	35,084	3,024
Turkey	27,271	1,847
Cuba	57,320	4,736
St. Thomas	23,925	1,859
United States	1,666,089	155,831
Brazil	67,143	4,314
Buenos Ayres	29,523	1,563
Gibraltar	17,718	1,633
British possessions in S. Africa	27,222	2,359
British East Indies	30,076	2,483
British North America	113,378	9,344
Other countries	137,932	12,682
	3,361,498	£322,318

Unenumerated:—

To	£	To	£
Hanse Towns - -	136	British East Indies -	361
France - - -	160	British West Indies -	668
New Grenada - -	480	Other countries - -	528
Brazil - - -	1,318		
Gibraltar - - -	120		£3,771

LINSEED. (*Graine de lin*, Fr.; *Leinsame*, Germ.) The seed of the flax, *Linum Usitatissimum*, which is indigenous to our islands, and is cultivated extensively in this and other countries for its seed, and for *flax*. Linseed contains in its dry state, 11·265 of oil; 0·146 of wax; 2·4808 of a soft resin; 0·550 of a colouring resinous matter; 0·926 of a yellowish substance analogous to tannin; 6·154 of gum; 15·12 of vegetable mucilage; 1·48 of starch; 2·932 of gluten; 2·782 of albumine; 10·884 of saccharine extractive; 44·382 of envelopes, including some vegetable mucilage. It contains also free acetic acid; some acetate, sulphate, and muriate of potash, phosphate and sulphate of lime: phosphate of magnesia; and silica.

LINSEED OIL is obtained from linseed by first bruising the seeds, grinding them, and subjecting them to violent pressure, either by means of wedges, or of the hydraulic or screw press. Cold drawn linseed oil is obtained cold, and is paler coloured, less odorous, and has less taste than that which is obtained when heat is applied.

It is usual to employ a steam heat of about 200° Fahr. By cold expression the seeds yield about 20 per cent., while by the aid of heat nearly 27 per cent. of oil can be obtained. The ultimate composition of linseed oil is carbon 76·014, hydrogen 11·351, and oxygen 12·635; its proximate constituents being oleic and margaric acids, and glycerine. Linseed oil is much used as a vehicle for colours by the painter. If linseed oil is exposed in a thin coat to the air it absorbs oxygen and becomes tenacious, and in many respects like caoutchouc: upon this property mainly depends its use in the arts. To secure this more readily a drying process is adopted, which must be described.

When linseed oil is carefully agitated with acetate of lead (tribasic acetate of lead), and the mixture allowed to clear by settling, a copious white cloudy precipitate forms, containing oxide of lead, whilst the raw oil is converted into a drying oil of a pale straw colour, forming an excellent varnish, which, when applied in thin layers, dries perfectly in twenty-four hours. It contains from four to five per cent. of oxide of lead in solution. The following proportions appear to be the most advantageous for its preparation.

In a bottle containing 4½ pints of rain water, 18 ounces of neutral acetate of lead are placed, and when the solution is complete, 18 ounces of litharge in a very fine powder are added; the whole is then allowed to stand in a moderately warm place, frequently agitating it to assist the solution of the litharge. This solution may be considered as complete when no more small scales are apparent. The deposit of a shining white colour (sexbasic acetate of lead) may be separated by filtration. This conversion of the neutral acetate of lead into vinegar of lead, by means of litharge and water, is effected in about a quarter of an hour, if the mixture be heated to ebullition. When heat is not applied, the process will usually take three or four days. The solution of vinegar of lead, or tribasic acetate of lead, thus formed, is sufficient for the preparation of 22 lbs. of drying oil. For this purpose, the solution is diluted with an equal volume of rain water, and to it is gradually added, with constant agitation, 22 lbs. of oil, with which 18 ounces of litharge have previously been mixed.

When the points of contact between the lead solution and the oil have been frequently renewed by agitation of the mixture three or four times a day, and the mixture allowed to settle in a warm place, the limpid straw-coloured oil rises to the surface, leaving a copious whitish deposit. The watery solution rendered clear by filtration, contains intact all the acetate of lead first employed, and may be used in the next operation, after the addition to it as before of 18 ounces of litharge.

By filtration through paper or cotton the oil may be obtained as limpid as water, and by exposure to the light of the sun it may also be bleached.

Should a drying oil be required absolutely free from lead, it may be obtained by the addition of dilute sulphuric acid to the above, when, on being allowed to stand, a deposit of sulphate of lead will take place, and the clear oil may be obtained free from all trace of lead.

Linseed oil was at one time much used in the preparation of a liniment, which, as it is one of the very best possible applications to a burnt surface, cannot be too generally known. *If equal parts of limewater and linseed oil* are agitated together, they form a thick liniment, which may be applied to the burn with a brush or feather. It relieves at once from pain, and forming a pellicle, protects the abraded parts from the air. The *linimentum calcis* of the Pharmacopœia is equal parts of

limewater and olive oil; this is a more elegant but a less effective preparation. *See* OIL.

LINT *for Surgery*, was formerly prepared by scraping up linen by the hand; the preparation of it, however, has been made the subject of a patent by Mr. Thomas Ross, which consists in the employment of peculiarly constructed scrapers for abrading the surface of the linen cloth, and producing a pile or nap upon it. The scrapers are worked by a rotary motion.

Instead of rotary scrapers, a reciprocating pendulous movement is sometimes applied to a single scraper. Chisel-formed blades are claimed by the patentee as scrapers for raising the pile, by working with the bevel edges forwards, so as to scrape and not to cut the fabric. He has in the rotary form a ledge or bed concentric with the axis of the scraper, which he also claims; both of which seem to be serviceable. Several kinds of lint-making machines are now employed, but as they all partake more or less the above principles they do not require description.

LIQUATION (Eng. and Fr.; *Saigerung*, Germ.) is the process of sweating out, by a regulated heat, from an alloy, a more easily fusible metal, from the interstices of a metal, which is more difficult of fusion. Lead and antimony are the metals most commonly subjected to liquation: lead for the purpose of removing by its superior affinity the silver present in any complex alloy; antimony as an easy means of separating it from its combinations in the ores.

Figs. 1138, 1139, 1140, represent the celebrated antimonial liquation furnaces of Malbosc, in the department of Ardèche, in France. *Fig.* 1138, is a ground plan taken at the level of the draught holes *g g*, *fig.* 1139, and of the dotted line E F; *fig.* 1139, is a vertical section through the dotted line A B, of *fig.* 1138; and *fig.* 1140, is a vertical section through the dotted line C D of *fig.* 1138. In the three figures, the same letters denote like objects. *a*, *b*, *c* are three grates upon the same level above the floor of the works, 4½ feet long, by 10½ inches broad; between which are two rectangular galleries, *d e*, which pass transversely through the whole furnace, and lie at a level of 12 inches above the ground. They are separated by two walls from the three fire places. The walls have three openings *f*, *g*, *h*, alternately placed for the flames to play through. The ends of these

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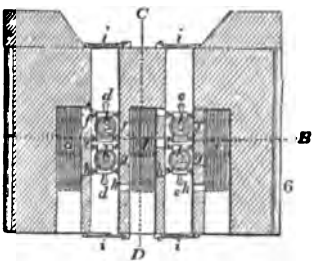

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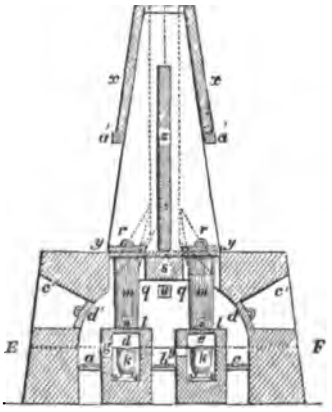

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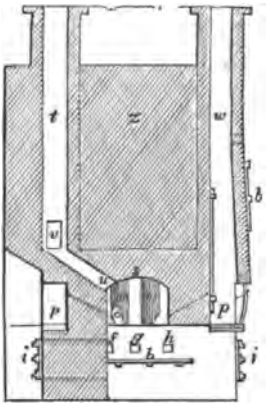


galleries are shut in with iron doors *i*, *i*, containing peep holes. In each gallery are two conical cast-iron crucibles *k k*, into which the *eliquating* sulphuret of antimony drops. Their height is from 12 to 14 inches; the width of the mouth is 10 inches, that of the bottom is 6, and the thickness four-tenths of an inch. They are coated over with fire-clay, to prevent the sulphuret from acting upon them; and they stand upon cast-iron pedestals with projecting ears, to facilitate their removal from the gallery or platform. Both of these galleries are lined with tiles of fire-clay *l l*, which also serve as supports to the vertical liquation tubes *m m*, made of the same clay. The tiles are

somewhat curved towards the middle, for the purpose of receiving the lower ends of these tubes, and have a small hole at *n*, through which the liquid sulphuret flows down into the crucible.

The liquation tubes are conical, the internal diameter at top being 10 inches, at bottom 8; the length fully 40 inches, and the thickness six-tenths of an inch. They have at their lower ends notches or slits, *o*, *fig.* 1140, from 3 to 5 inches long, which look outwards, to make them accessible from the front and back part of the furnaces through small conical openings *p p*, in the walls. These are closed during the operation with clay stoppers, and are opened only when the gangue, rubbish, and cinders are to be raked out. The liquation tubes pass across the arch of the furnace *q q*, the space of the arch being wider than the tubes; they are shut in at top with fire-covers *r r*. *s s*, the middle part of the arch, immediately under the middle grate, is barrel-shaped, so that both arches are abutted together. The flames, after playing round about the sides of the liquation tubes, pass off through three openings and flues into the chimney *t*, about 13 feet high; *u*, being the one opening, and *v*, the two others, which are provided with register plates. In front of the furnace is a smoke flue *w*, to carry off the sulphureous vapours exhaled during the clearing out of the rubbish and slag; another, *x*, begins over *y y*, at the top of the tubes; a wall *z*, separates the smoke flue into halves, so that the workmen upon the one side may not be incommoded by the fumes of the other. This wall connects at the same time the front flue *w* with the chimney *t*. *a' a'* and *b' b'* are iron and wooden bearer beams and rods for strengthening the smoke-flue. *c' c'* are arches upon both sides of the furnace, which become narrower from without inwards, and are closed with well fitted plates *d' d'*. They serve in particular circumstances to allow the interior to be inspected, and to see if either of the liquation furnaces be out of order. Each tube is charged with 500 lbs. of antimonial ore, previously warmed; in a short time the sulphuret of antimony begins to flow off. When the liquation ceases, the cinders are raked out by the side openings, and the tubes are charged afresh. The luted iron crucibles are allowed to become three-fourths full, are then drawn out from the galleries, left to cool and emptied. The ingot weighs about 85 pounds. The average duration of the tubes is 3 weeks. This plan is proved to be an exceedingly economical one.

LIQUEURS, LIQUORISTE. Names given by the French, and adopted into our language, to certain aromatic alcoholic cordials, and to the manufacturer of them.

Some liqueurs are prepared by infusing the woods, fruits, or flowers, in either water or alcohol, and adding thereto sugar and colouring matter. Others are distilled from the flavouring agents.

Many of the liqueurs are of very compound character, as the following recipes will show.

Martinique Noyeau:—Put into a stone jar,

Preserved guavas and their syrup, or the jelly of that fruit	½ lb.
Oil of sweet almonds	1 oz.
Sweet almonds, beaten fine	1
Bitter „ „	1
Preserved ginger and its syrup	2
Cinnamon and cloves (bruised) of each	½
Nutmeg and Pimento „ „	½
Jamaica ginger „	½
Candied lemon and citron, of each	1
White sugar candy (powdered)	14
Proof spirit of wine	5 quarts.

Beat the oil with a little brandy, and mix it with the almonds, when beaten to a paste with orange flower water. Stop up the jar securely, and let it remain in a warm room, or in the sun, shaking it often, for a fortnight. Keep it in the jar for twelve or fifteen months; then strain it, and filter repeatedly until it is as clear as spring water. Rinse phials or half pint bottles, with any white wine, drain them and fill. Cork and seal well. In six months it will be fit for use, if required, but will improve greatly by age. — *Robinson.*

Tears of the Widow of Malabar.—To ten pounds of spirit (pale brandy), add 4 pounds of white sugar, and 4 pints of water, adding 4 drachms of powdered cinnamon, 48 grains of cloves, and the same quantity of mace; colour with caramel.

The Sighs of Love.—Spirit, water, and sugar as above. Perfume with otto of roses, and slightly colour with cochineal.

Absinthe. — Take of the tops of wormwood, 4 pounds, root of angelica, calamus aromaticus, aniseed, leaves of dittany, of each, 1 oz.; alcohol, four gallons.

Macerate these substances during eight days, add a little water, and distill by a

gentle fire until two gallons are obtained. This is reduced to a proof spirit, and a few drops of the oil of aniseed added.

These forms exemplify the character of all kinds of liqueurs. They are coloured *yellow* by the colouring matter of *carthamus*. *Fawn* is produced by caramel; *red*, by cochineal; *violet*, by litmus, or archil; *blue* by the sulphate of indigo; *green*, by mixing the blue and the yellow together.

Ratafia, is the generic name, in France, of *liqueurs* compounded with alcohol, sugar, and the odoriferous or flavouring principles of vegetables. Bruised cherries with their stones are infused in spirit of wine to make the ratafia of Grenoble *de Teyssère*. The liquor being boiled and filtered, is flavoured, when cold, with spirit of *noyeau*, made by distilling water off the bruised bitter kernels of apricots, and mixing it with alcohol. Syrup of bay laurel and galango are also added.

LIQUID AMBAR. See AMBAR, LIQUID.

LIQUORICE (*Glycyrrhiza Officinalis*; from *glykys*, sweet, and *rhiza*, a root). The root only is employed; these roots are thick, long, and running deep in the ground.

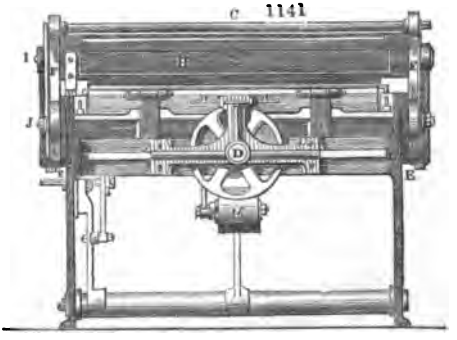
Besides the use of liquoric roots in medicine, they are also employed in brewing, and are pretty extensively grown for these purposes in some parts of England. Liquorice requires a rich deep dry sandy soil, which, previous to forming a new plantation, should be trenched to the depth of about three feet, and a liberal allowance of manure regularly mixed with the earth in trenching. The plants which are procured by slipping them from those in old plantations are, either in February or March, dibbled in rows three feet apart, and from eighteen inches to two feet in the row. They require three summers' growth before being fit for use, when the roots are obtained by retrenching the whole, and they are then stored in sand for their preservation until required. — *Peter Lawson.*

LITHARGE (Eng. and Fr.; *Glätte*, Germ.) is the fused yellow protoxide of lead, which on cooling passes into a mass consisting of small six-sided plates, of a reddish yellow colour and semitransparent. It generally contains more or less red lead, whence the variations of its colour, and carbonic acid, especially when it has been exposed to the air for some time. See LEAD and SILVER, for its mode of preparation.

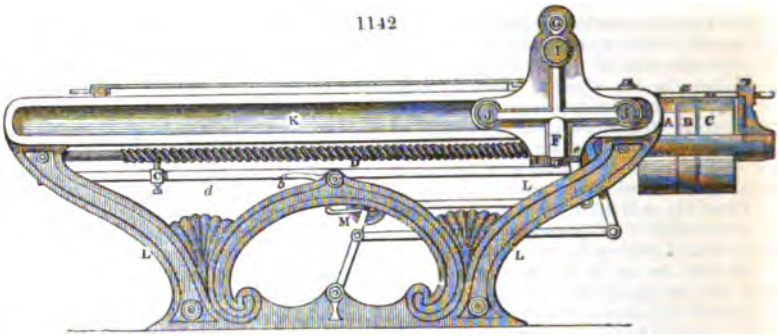
LITHIA is a simple earthy or alkaline substance, discovered in the minerals called petalite and triphane. It is white, very caustic, reddens litmus and red cabbage, and saturates acids with great facility. When exposed to the air it attracts humidity and carbonic acid. It is more soluble in water than baryta; and has such a strong affinity for it as to be obtained only in the state of a hydrate. It forms neutral salts with all the acids. It is most remarkable for its power of acting upon or corroding platinum.

LITHIUM is the metallic basis of lithia; the latter substance consists of 100 of metal, and 123 of oxygen. Neither lithium nor its oxide are of any use in the arts.

LITHOGRAPHIC PRESS. The lithographic press in common use has long been regarded as a very inadequate machine. The amount of manual power required to work it, and the slow speed at which, under the most favourable circumstances, copies can be produced, disables lithography in its competition with letter-press. A career of brilliant success has attended the efforts of scientific men towards speed and perfection in this latter branch of the art; and the present printing machines surpass the hand-press somewhat in the same ratio as does our express speed the jog-trot of our forefathers. The engravings annexed, *figs.* 1141, 1142, will serve to illustrate Messrs. Napier & Sons' improvements upon the lithographic press. The machine is arranged to be driven by steam power; has belts, "crossed" and "open," supposed to be in connection with the engine, and to run upon the pulleys A, B, C. The crank pulley, B, is fixed on the screw-spindle D, and the other two work loose, or "dead," on the same spindle; these bands with their striking forks, *a*, are arranged so as to be brought alternately upon the fixed pulley B, and thus a reversing motion is given to the screw. The nut in which the screw works is fixed to a crosspiece E, which braces the side frames F F, together at bottom, while the bar G, performs the same office at top; the scraper-box, H, is sustained between



these frames at bearings I, and is so fitted as to work freely. To support the frames and scraper-box independent of the screw and maintain them in



position, allowing freedom of action, the rollers J, J, are provided, which run in the planed recesses, K, along the top of the main standards L.

The machine is shown with its tympan down, ready for starting; this is effected by pressing lightly upon the lever, *b*, which raises a catch, and allows the weight M, to descend in the direction of its present inclination, and act upon the connections with the striking forks, so as to bring one of the bands upon the fast pulley, B, and make the scraper and its frames move forward. The return is caused by the frame, F, coming in contact with a stop C, which, yielding, acts upon the striking forks by its bar *d*, upon which it may be adjusted to give the travel required. On the return being accomplished, the machine stops itself by a striking action against stop *e*, the catch *b* falling in to prevent the weight descending to its full throw, and thus retaining the two bands upon the two dead pulleys, A and C, while the machine is prepared for another impression.

The action of the scraper is peculiar and novel; it is balanced, so that its tendency is to remain slightly raised, but in its forward movement, and at the point desired, it is made to descend by a stop fixed upon the top of the main standard, L, into a position vertical, or nearly so, in which position it is retained by its own onward progress against strong abutments projecting from the frames, F; on the return it resumes its raised position and passes back without impediment. The scraper may be adjusted to give the pressure desired, or the table on which the stone is placed regulated by screws.

The advantages embodied in this machine will be at once recognised by those interested. The pulling down of the scraper, and the labour and inconvenience attendant upon that operation, are entirely superseded by the simple and effectual valve-like movement just explained, which forms the ground work of this combination, although it will alike apply to the press work by hand, and is the most striking novelty in the machine.

LITHOGRAPHY. Though this subject belongs rather to the arts of taste and design than to productive manufactures, its chemical principles fall within the province of this Dictionary.

The term *lithography* is derived from λιθος, *a stone*, and γραφη, *writing*, and designates the art of throwing off impressions upon paper of figures and writing previously traced upon stone. The processes of this art are founded: —

1. Upon the adhesion to a grained or smoothly-polished limestone, of an encaustic fat which forms the lines or traces.

2. Upon the power acquired by the parts penetrated by this encaustic, of attracting to themselves, and becoming covered with, a printer's ink, having linseed oil for its basis.

3. Upon the interposition of a film of water, which prevents the adhesion of the ink in all the parts of the surface of the stone not impregnated with the encaustic.

4. Lastly, upon a pressure applied to the stone, such as to transfer to paper the greater part of the ink which covers the greasy tracings or drawings of the encaustic.

The lithographic stones of the best quality are still procured from the quarry of Solenhofen, a village at no great distance from Munich, where this mode of printing had its birth. They resemble in their aspect the yellowish-white lias of Bath, but their geological place is much higher that the lias. Abundant quarries of these fine-grained limestones occur in the county of Pappenheim, along the banks of the Danube, presenting slabs of every required degree of thickness, parted by regular seams, and ready

for removal with very little violence. The good quality of a lithographic stone is generally denoted by the following characters; its hue is of a yellowish grey, and uniform throughout; it is free from veins, fibres, and spots; a steel point makes an impression on it with difficulty; and the splinters broken off from it by the hammer display a conchoidal fracture.

The Munich stones are retailed on the spot in slabs or layers of equal thickness; they are quarried with the aid of a saw, so as to sacrifice as little as possible of the irregular edges of the rectangular tables or plates. One of the broad faces is then dressed, and coarsely smoothed. The thickness of these stones is nearly proportional to their other dimensions; and varies from 1½ inches to 3 inches.

In each lithographic establishment, the stones receive their finishing, dressing, and polishing; which are performed like the grinding and polishing of mirror plate. The work is done by hand, by rubbing circularly a movable slab over another in a horizontal position, with fine sifted sand and water interposed between the two. The style of *work* that the stone is intended to produce determines the kind of polish that it should get. For crayon drawing the stone should be merely grained more or less *fine* according to the fancy of the draughtsman. The higher the finish of the surface the softer are the drawings; but the printing process becomes sooner *pasty*, and a smaller number of impressions can be taken. *Works in ink* require the stone to be more softened down, and finally polished with pumice and a little water. The stones thus prepared are packed for use with white paper interposed between their faces.

Zinc plates are sometimes used in lieu of stones; they are prepared by graining the surface with fine sand, rubbed over by means of a small piece of the metal. Zinc takes a finer surface than stone, and yields more delicate impressions; but great care is necessary in keeping it dry, so that it does not corrode; this is almost the only objection to its more general use, for it is far more convenient to handle and move about than heavy stones.

Lithographic crayons. — Fine lithographic prints cannot be obtained unless the crayons possess every requisite quality. The ingredients composing them ought to be of such a nature as to adhere strongly to the stone, both after the drawing has undergone the preparation of the acid, and during the press-work. They should be hard enough to admit of a fine point, and trace delicate lines without risk of breaking. The following composition has been successfully employed for crayons by MM. Bernard and Delarue, at Paris: —

Pure wax (first quality)	4 parts.
Dry white tallow soap	2 „
White tallow	2 „
Gum lac	2 „
Lamp black, enough to give a dark tint	1 „
Occasionally copal varnish	1 „

The wax should be melted over a gentle fire, and the lac, broken to bits, is then added by degrees, stirring all the while with a spatula; the soap is next introduced in fine shavings; and when the mixture of these substances is very intimately accomplished, the copal-varnish, incorporated with the lamp black, is poured in. The heat and agitation are continued till the paste has acquired a suitable consistence; which may be recognised by taking out a little of it, letting it cool on a plate, and trying its quality with a penknife. This composition, on being cut, should afford brittle slices The boiling may be quickened by setting the rising vapours on fire, which increases the temperature, and renders the exhalations less offensive. When ready, it is to be poured into a brass mould, made of two semi-cylinders joined together by clasps or rings, forming between them a cylindric tube of the crayon size. The mould should be previously rubbed with a greasy cloth.

The soap and tallow are to be put into a small goblet and covered up. When the whole is thoroughly fused by heat, and no clots remain, the black is gradually sprinkled in with careful stirring.

Lithograpic ink is prepared nearly on the same principle: —

Wax	16 parts.
Tallow	6 „
Hard tallow soap	6 „
Shell-lac	12 „
Mastic in tears	8 „
Venice turpentine	1 „
Lamp black	4 „

The mastic and lac, previously ground together, are to be carefully heated in the turpentine; the wax and tallow must be added after they are taken off the fire and when their solution is effected, the soap shavings are to be thrown in. Lastly, the lamp

black is to be well intermixed. Whenever the union is accomplished by heat, the operation is finished; the liquor is left to cool a little, then poured out on tables, and, when cold, cut into square rods.

Lithographic ink of good quality ought to be susceptible of forming an emulsion so attenuated, that it may appear to be dissolved when rubbed upon a hard body in distilled or river water. It should flow in the pen, but not spread on the stone; capable of forming delicate traces, and very black, to show its delineations. The most essential quality of the ink is to sink well into the stone, so as to reproduce the most delicate outlines of the drawing, and to afford numerous impressions. It must therefore be able to resist the acid with which the stone is moistened in the preparation, without letting any of its greasy matter escape.

M. de Lasteyrie states that after having tried a great many combinations, he gives the preference to the following: —

Tallow soap dried	30 parts.
Mastic in tears	30 „
White soda of commerce	30 „
Shell-lac	150 „
Lamp-black	12 „

The soap is first put into the goblet and melted over the fire; the lac being added it fuses immediately; the soda is then introduced, and next the mastic, stirring all the while with a spatula. A brisk fire is applied till all these materials are melted completely, when the whole is poured out into the mould.

The inks now prescribed may be employed either with the pen and the hair pencil, for writings, black-lead drawings, *aqua tinta*, mixed drawings, those which represent engravings on wood (woodcuts), &c. When the ink is to be used it is to be rubbed down with water, in the manner of China ink, till the shade be of the requisite depth. The temperature of the place ought to be from 84° to 90° Fahr., or the saucer in which the ink stick is rubbed should be set in a heated plate. No more ink should be dissolved than is to be used at the time, for it rarely keeps in the liquid state for 24 hours; and it should be covered or corked up.

Autographic paper. — Autography, or the operation by which a writing or a drawing is transferred from paper to stone, presents not merely a means of abridging labour, but also that of *re*verting the writings or drawings into the direction in which they were traced, whilst, if executed directly upon the stone, the impression given by it is *in*verted. Hence, a writing upon stone must be inverted from right to left to obtain direct impressions. But the art of writing thus is tedious and difficult to acquire, while, by means of the autographic paper and the transfer, proofs are obtained in the same direction with the writing and drawing.

Autographic ink. — It must be fatter and softer than that applied directly to the stone, so that though dry upon the paper, it may still preserve sufficient viscidity to adhere to the stone by mere pressure.

To compose this ink, we take —

White soap	100 parts.
White wax of the best quality	100 „
Mutton suet	30 „
Shell-lac	50 „
Mastic	50 „
Lamp black	30 or 35 „

These materials are to be melted as above described for the lithographic ink.

Lithographic ink and paper. — The following recipes have been much commended: —

Virgin or white wax	8 parts.
White soap	2 „
Shell-lac	2 „
Lamp black	3 table-spoonfuls.

Preparation. — The wax and soap are to be melted together, and before they become so hot as to take fire, the lamp black is to be well stirred in with a spatula, and then the mixture should be allowed to burn for 30 seconds; the flame being extinguished, the lac is added by degrees, carefully stirring all the time; the vessel is to be put upon the fire once more in order to complete the combination, and till the materials are either kindled or nearly so. After the flame is extinguished, the ink must be suffered to cool a little, and then put into the moulds.

With the ink crayons thus made, lines may be drawn as fine as with the point of the graver, and as full as can be desired, without risk of its spreading in the carriage. Its traces will remain unchanged on paper for years before being transferred.

Some may think it strange that there is no suet in the above composition, but it has

been found that ink containing it is only good when used soon after it is made, and when immediately transferred to the stone, while traces drawn on paper with the suet ink become defective after 4 or 5 days.

Lithographic paper. — Lay on the paper 3 successive coats of sheep-foot jelly, 1 layer of white starch, 1 layer of gamboge.

The first layer is applied with a sponge dipped in the solution of the hot jelly, very equally over the whole surface, but thin; and if the leaf be stretched upon a cord, the gelatine will be more uniform. The next two coats are to be laid on, until each is dry. The layer of starch is then to be applied with a sponge, and it will also be very thin and equal. The coat of gamboge is lastly to be applied in the same way. When the paper is dry, it must be smoothed by passing it through the lithographic press; and the more polished it is, the better does it take on the ink in fine lines.

Transfer. — When the paper is moistened, the transfer of the ink from the gamboge is perfect and infallible. The starch separates from the gelatine, and if, after taking the paper off the stone, we place it on a white slab of stone, and pour hot water over it, it will resume its primitive state.

The coat of gamboge ought to be laid on the same day it is dissolved, as by keeping it becomes of an oily nature; in this state it does not obstruct the transfer, but it gives a gloss to the paper which renders the drawing or tracing more difficult, especially to persons little accustomed to lithography.

The starch paste can be employed only when cold, the day after it is made, and after having the skin removed from its surface.

A leaf of such lithographic paper may be made in two minutes.

In transferring a writing, an ink drawing, or a lithographic crayon, even the impression of a copper-plate, to the stone, it is necessary, 1, that the impressions be made upon a thin and slender body like common paper; 2, that they may be detached and fixed totally on the stone by means of pressure; but as the ink of a drawing sinks to a certain depth in paper, and adheres rather strongly, it would be difficult to detach all its parts, were there not previously put between the paper and the traces a body capable of being separated from the paper, and of losing its adhesion to it by means of the water with which it is damped. In order to produce this effect, the paper gets a certain preparation, which consists in coating it over with a kind of paste ready to receive every delineation without suffering it to penetrate into the paper. There are different modes of communicating this property to paper.

Besides the above, the following may be tried. Take an unsized paper, rather strong, and cover it with a varnish composed of: — Starch, 120 parts; gum arabic, 40 parts; alum, 20 parts.

A paste of moderate consistence must be made with the starch and some water, with the aid of heat, into which the gum and alum are to be thrown, each previously dissolved in separate vessels. When the whole is well mixed, it is to be applied, still hot, on the leaves of paper, with a flat smooth brush. A tint of yellow colour may be given to the varnish with a decoction of the berries of Avignon, commonly called French berries by our dyers. The paper is to be dried, and smoothed by passing under the scraper of the lithographic press.

Steel pens are employed for writing and drawing with ink on the lithographic stones; in many establishments a sable brush is more frequently used.

Engraving on stone, for maps, geometrical drawings of every kind, patent inventions, machinery, &c., is performed with a diamond point as clearly and distinctly as if executed on copper or steel plates; to print these engraved stones, the ink should be laid on with a dabber, not a roller. Another method is by preparing the surface of the stone with a thin covering, or etching ground, of gum and black, upon which the design is traced or engraved with an etching point; it then appears in *white* lines upon a black surface. In this state the stone is taken to the printer, who applies ink to the engraved part, and washing off the gum, the drawing appears in *black* lines upon the white surface of the stone, and after being submitted to the process of fixing, described below, is ready for printing.

Lithotint, a process of drawing upon stone was adopted, first, by Mr. J. D. Harding, a few years back, and since by one or two other artists; several works were at the time executed by this method, which consists in *painting* the subject with a camel hair pencil, dipped in a preparation of liquid lithographic chalk, using the latter as if it were an ordinary colour, or Indian ink, sepia, &c. The results of this process were, however, so uncertain in printing, that it has been almost, if not entirely, abandoned.

The process of printing a subject executed in lithography is as follows: — The drawing is first executed by the artist on the stone in as perfect and finished a manner as if done on paper or card-board: the stone is then washed over with nitric acid, diluted with gum, which neutralises the alkali, or soap, contained in the chalk,

fixes the drawing, and cleanses the stone at the same time: this is technically called *etching*. The acid is then washed off with cold water, and any particles of the crayon or other substances which may have adhered to the surface, are removed by the application of a sponge dipped in spirits of turpentine: the stone is now ready for printing: it is slightly wetted, charged with printing-ink by means of a roller, the sheet of paper, which is to receive the impression, is laid on it in a damp state, and the whole is passed through the press.

Chromolithography, or printing in colours from stones (χρῶμα, colour), is a comparatively recent introduction, but has been brought to such perfection, that works of art of the highest pictorial excellence are sometimes so closely imitated, as to deceive very competent judges. A portrait of Shakspeare, for example, executed in chromolithography by Mr. Vincent Brooks, of London, from an old oil painting, is so marvellous a copy of the original as almost to defy detection. Chromolithography, as a beautiful medium of illustration, is now in very general use: the process may be thus described. A drawing of the subject, in outline, on transfer tracing-paper, is made in the ordinary way: when transferred to a stone, this drawing is called the *keystone*, and it serves as a guide to all the others, for it must be transferred to as many different stones as there are colours in the subject; as many as thirty stones have been used in the production of one coloured print. The first stone required, generally for flat, local tints, is covered with lithographic ink where the parts should be of solid colour: the different gradations are produced by rubbing the stone with *rubbing-stuff*, or tint-ink, made of soap, shell lac, &c. &c., and with a painted lithographic chalk where necessary; the stone is then washed over with nitrous acid, and goes through the entire process described above. A roller charged with lithographic printing-ink is then passed over it to ascertain if the drawing comes as desired; and the ink is immediately afterwards washed off with turpentine: if satisfactory, this stone is ready for printing, and is worked off in the requisite colour; the next stone undergoes the same process for another colour, and so with the rest till the work is complete: it will of course, be understood, that before any simple impression is finished, it will have to pass through as many separate printings as there are drawings on stones. The colours used in printing are ground up with burnt linseed oil, termed *varnish*. — J. D.

LITHOMARGE. A silicate of alumina, in many respects resembling China clay or kaolin, which see.

LITMUS (*Tournesol*, Fr.; *Lackmus*, Germ.) is prepared in Holland from the species of lichen called *Lecanora tartarea*, *Roccella tartarea*. The ground lichens are first treated with urine containing a little potash, and allowed to ferment for several weeks, whereby they produce a purple-red; the coloured liquor, treated with quicklime and some more urine, is set again to ferment during two or three weeks, then it is mixed with chalk or gypsum into a paste, which is formed into small cubical pieces by being pressed into brass moulds, and dried in the shade. Litmus has a violet-blue colour, is easy to pulverise, is partially soluble in water and dilute alcohol, leaving a residuum consisting of carbonate of lime, of clay, silica, gypsum, and oxide of iron combined with the dye. The colour of litmus is not altered by alkalies, but is reddened by acids; and is therefore used in chemistry as a delicate test of acidity, either in the state of solution or of unsized paper stained with it. See LICHEN.

The preparation of litmus has been described by Ferber, Moreloz, and others.

Dr. Pereira, writes, "Litmus is imported from Holland, in the form of small, rectangular, light, and friable cakes of an indigo blue colour. Examined by the microscope, we find sporules and portions of the epidermis and mesothallus of some species of lichen, moss, leaves, sand, &c. The odour of the cakes is that of indigo and violets. The violet odour is acquired while the mixture is undergoing fermentation, and is common to all the tinctorial lichens. It has led some writers into the error of supposing that the litmus makers use Florentine orris in the manufacture of litmus. The indigo colour depends on the presence of indigo in the litmus cakes."

LITMUS PAPER. Paper coloured with an infusion of litmus, used as a test for the presence of acids.

Faraday, in his *Chemical Manipulation*, recommends an infusion of one ounce of litmus, and half a pint of hot water. Bibulous paper is saturated with this. Professor Graham prefers good letter paper to the unsized paper. In order to obtain very delicate test-paper, the alkali in the litmus must be *almost* neutralised by a minute portion of acid.

LITTORAL (*a geological term*). Belonging to the sea-shore.

LIVI-DIBI. Another name for Divi-divi. See LEATHER.

LIXIVIATION (*Lessivage*, Fr.; *Auslagen*, Germ.) signifies the abstraction by water of the soluble alkaline or saline matters present in any earthy admixture; as from that of quicklime and potashes to make potash lye, from that of effloresced alum schist to make aluminous liquors, &c.

LLAMA. A genus of animals belonging to the class *Mammalia*, order *Ungulata*, family *Bovidæ*, and tribe *Camelina*. They are the camels of South America, to which country they are confined. In the wild state the llamas keep together in herds of from one to two hundred. There are two distinct species found wild in South America, inhabiting the Peruvian Alps, the Pampas, and the mountains of Chili. These animals are used as beasts of burthen; cords and sacks, as well as stuffs for ponchos, &c., are fabricated from their wool; and their bones are converted into instruments for weaving the same. The Alpaca, which is a variety of the llama, has given its name to a cloth manufactured from its hair; and this has become so valuable, that attempts have been made to naturalise the animal in Europe. The success, however, which has attended these attempts has not been great. The following note from the *Penny Cyclopedia*, article Llama, is important.

"In reference to the wool, we may here state that a herd of thirty-six, including the kinds called llamas, alpacas, and vicunas or vigonias, were sent from Lima (Peru) and Conception (Chili) to Buenos Ayres by journeys of two or three leagues. To those who may be inclined to import these animals, it may be necessary to state that they were fed during the journey with potatoes, maize, and hay. As soon, however, as the potatoes were exhausted, constipation came on so obstinately, that medical relief was required. They were shipped as a present from Godoy, the Prince of Peace, to the Empress Josephine, but only eleven arrived at Cadiz in 1808, just as Godoy fell into disgrace. Here two died, and the rest were near being thrown into the sea by the infuriated rabble, in their detestation of the late minister and minion. The poor llamas were however saved from the tender mercies of the populace by the governor of Cadiz, and were consigned to Don Francisco de Theran of Andalusia, who had a fine menagerie at San Lucar de Barrameda. When the French occupied the province, Marshal Soult protected them; and M. Bury St. Vincent, who was with the army, studied their habits, and executed drawings of them, which were lost at the battle of Vittoria. M. Bury paid great attention to their wool, and some from each kind was sent to the Academy of Sciences at Paris. From the report of the French naturalist and the philosophical Spaniard, it would appear that the fleece of the alpa-vigonia (produced by a cross between a vigonia and an alpaca) has much greater length than any other variety, and is six times heavier."

The following is from *James's History of the Worsted Manufacture in England*, p. 652:—

To commence with the earliest mention of the alpaca, we must recur to so early a period as the year 1525, when Pizarro and his ferocious companions invaded Peru. It is related by the Spanish historians, that they found there four varieties of sheep; two, the guanaco and the vicuna, in a wild state, ranging the mountainous tracts of South America; and the others, the llama and the pacos, or alpaca, domesticated. The former of these domestic animals, partaking somewhat of the nature and size of the Arabian camel, was in like manner employed as a beast of burden. Though in many features similar to the llama, the alpaca had several clear marks of distinction, and among others was less, and the fleece much longer and softer in fibre. In the sixteenth century, and even from the remotest times, the Peruvians being comparatively (to the other tribes of the great continent of America) a civilised people, and well acquainted with the arts of spinning and weaving, fabricated from alpaca wool textures of much delicacy and beauty, which were highly prized as articles of dress. And that the use of them had prevailed for centuries is demonstrated by the opening of several very ancient tombs of the Peruvians, in which the dead had been enwrapped in stuffs made from the fleece of the alpaca.

In general, the alpaca ranges about four feet in height, the size of a full grown deer, and, like it, is of graceful appearance. Its fleece is superior to the sheep in length and softness, averaging six inches (the length of the staple of the alpaca fleece is on an average much less than formerly, probably from being shorn oftener), and sometimes it has been procured even of an extraordinary length; a specimen shown at the Great Exhibition, by Messrs. Walter Milligan and Son, reaching to forty-two inches in length. The fleeces, when annually shorn, range from five to six pounds. Contrary to experience in other descriptions of wool, the fibre of the Alpaca fleece acquires strength without coarseness; besides, each filament appears straight, well formed, and free from crispness, and the quality is more uniform throughout the fleece. There is also a transparency, a glittering brightness upon the surface, giving it the glossiness of silk, which is enhanced on its passing through the dye-vat. It is also distinguished by softness and elasticity, essential properties in the manufacture of fine goods, being exempt from spiral, curly, and shaggy defects; and it spins, when treated properly according to the present improved method, easily, and yields an even, strong, and true thread. With all these remarkable qualities, it was long before the value of alpaca wool was known or appreciated in this country.

Recurring to the application of the alpaca fleece to manufacturing purposes in England, it was long delayed. Though so early as the year 1807, the British troops returning from the attack of Buenos Ayres brought with them a few bags of this wool, which were submitted for inspection in London; but, observes Walton in his work on alpaca, "owing to the difficulty of spinning it, or the prejudice of our manufacturers, it did not then come into notice," and for more than twenty years the attempt does not seem to have been renewed; thus depriving, for that period, the country of the advantage derived from this notable manufacture.

According to the best authorities, the first person in England who introduced a marketable fabric made from this material was Mr. Benjamin Outram, a scientific manufacturer of Greetland, near Halifax, who, about the year 1830, surmounted, with much difficulty, the obstacles encountered in spinning the wool, and eventually produced an article which sold at high prices for ladies' carriage shawls and cloakings; but their value arose more from being rare and curious articles than from intrinsic worth.

These were, it is well established, quite destitute of the peculiar gloss and beauty which distinguish the alpaca lustres and fabrics of later times, and after a short period the manufacture was abandoned.

About the same time as Mr. Outram was weaving goods from alpaca, the wool attracted the notice of the Bradford spinners. Messrs. Wood and Walker spun it to some extent for camlet warps used in the Norwich trade. Owing to the cheapness of alpaca wool during the first years of its consumption in England, it was occasionally employed instead of English hog wool for preparing lasting and camblet warps, being spun to about No. 48.

The earliest manufacture of the alpaca wool into goods at Bradford appears to have occurred under these circumstances. In the commencement of 1832 some gentlemen, connected with the trade to the west coast of South America, were on a visit at the house of J. Garnett, Esq., of Clithero, and, on their alluding to the difficulty of meeting with suitable returns for goods forwarded to that part of the world, he suggested to them the transmission of alpaca wool, and offered, if they would send him a few pounds weight, to ascertain its value for manufacturing purposes. In a few months he received some samples of alpaca wool, which, on the 2nd of October, 1832, he forwarded to Messrs. Horsfall, of Bradford, with a request that they would test its value. Accordingly they fabricated from this wool a piece resembling heavy camblet, which they showed to the Leeds merchants; but the piece, not developing any peculiar qualities of alpaca, did not please, so that Messrs. Horsfall were not encouraged to proceed further with experiments. However, in the same year Messrs. Hoyam, Hall, and Co., spirited merchants of Liverpool, perceiving the value of the alpaca wool, directed their agents in Peru to purchase and ship over all the parcels of alpaca wool they could meet with; some of which, being sent to the Bradford district, was spun and manufactured by several parties there. The pieces chiefly fabricated from alpaca in the neighbourhood of Bradford were figures made with worsted warp and alpaca weft, the figure being raised and lustrous like union damasks. These goods were in vogue only for a limited time, for neither the figured nor plain ones seem to have suited the public taste.

Until the introduction of cotton warps into the worsted trade, it may safely be averred that the alpaca manufacture had not been developed, and would never have made much progress without being combined with cotton or silk warp. To Titus Salt, Esq., of Bradford, must undoubtedly be awarded the high praise of finally overcoming the difficulties of preparing and spinning the alpaca wool so as to produce an even and true thread, and, by combining it with cotton warps, which had then (1836) been imported into the trade of Bradford, improved the manufacture so as to make it one of the staple industries of the kingdom. He has, by an admirable adaptation of machinery, been enabled to work up the material with the ease of ordinary wool, and thus present beautiful alpaca stuffs at a reasonable rate. Every previous attempt had been made, so far as can be ascertained, with worsted warps, with which the alpaca did not easily assort.

About the year 1836 the alpaca trade had become established, and has since risen to much importance. After this period the manufacture rapidly extended. The great mercantile house of A. and S. Henry took very large quantities of alpaca stuffs, which began to be made in an endless variety of goods suited both for male and female dress, including scarfs, handkerchiefs, and cravats, plain and figured goods, both with silk and cotton warp, for ladies' dresses, dyed alpaca checks of beautiful texture, and a variety of grograms, codringtons, silk-striped, checked, and figured alpacas and alpaca linings. The demand for these various alpaca fabrics during the period between 1841 and 1846 remained uniform and steady.

At the commencement of the manufacture of alpaca goods with cotton warps (silk

was not used), the weft was spun from fine qualities of the wool into low numbers, and the pieces were made much richer and heavier than has been the case more recently, the demand having altered in favour of lighter and less costly cloth.

Most of the alpaca wool brought into the United Kingdom is unshipped at Liverpool, but a small portion is also carried to London. At these two ports, it may be asserted, the whole imported into this country is landed. It arrives in small bales, called ballots, weighing about seventy pounds, and is generally in an impure state, with different qualities mixed. Like the fleece of the sheep, that of the alpaca is composed of different qualities, so that the portion growing on the hind quarters is of an inferior description. The wool is sorted into about eight different qualities, each fitted for a particular class of goods. Owing to the dirty state of the fleeces, and the peculiar nature of the dusty particles arising during the progress of sorting, the operation is an unhealthy one, unless great care be taken by ventilation to counteract this baneful effect. After being sorted, it is at Saltaire washed and combed by machinery. Until of late years it was combed wholly by hand, and the combs used for the purpose were of a deeper pitch than those usually adopted for preparing sheep's wool, that is, those combs had a larger number of teeth than ordinary. The next process is to draw the sliver, which is perfected by an improved gill machine, especially adapted for this material. And here, in combing and preparing the alpaca wool, so as to make a clean, even, and glossy thread, lay the grand difficulty in the way of applying the alpaca fibre to the worsted manufacture, and which was so successfully surmounted by Mr. Salt.

The main articles now manufactured from alpaca wool consist of alpaca lustres, which are dyed, and alpaca mixtures, which are undyed, and both are made of cotton or silk warp. These plain goods may from their extensive and steady use be termed stock articles. Large quantities of fancy alpacas are made, but they are rapidly varying and are distinguished by innumerable names. The material is at present much shorter in staple than formerly, owing to the alpaca being shorn oftener, so that it is now commonly from five to eight inches in length. Nearly all the alpaca wool consumed in England is worked up in the Bradford district.

Dating from the year 1834, when the importation of alpaca wool sprung up as a permanent branch of commerce, the demand in this country has, with the exception of the last two years, on the whole been a growing one. Mr. Walton, in his work on the alpaca, exhibits the quantities exported chiefly to England until the year 1843, when the tariff law having come into operation, the returns began to be more correctly framed, and the alpaca wool was then classed by itself.

Years.	Lbs.	Years.	Lbs.
1834	5,700	1839	1,825,500
1835	184,400	1840	1,650,000
1836	199,000	1841	1,500,000
1837	385,800	1842	1,443,299
1838	459,300		

In the interval of these twelve years, the price had, with the demand, progressively increased: the price in 1834 only amounted to about eightpence halfpenny per pound: next year it reached nearly tenpence; the year after one shilling; in 1838, to upwards of one shilling and threepence halfpenny; and in 1839, to one shilling and fourpence per pound.

Since the year 1842, the returns of alpaca wool imported into this country are of a more reliable character. The following table has been drawn up from data furnished by the Board of Trade.

Years.	Lbs.	Years.	Lbs.
1843	1,458,032	1850	1,652,295
1844	635,357	1851	2,013,202
1845	1,261,905	1852	2,068,594
1846	1,554,287	1853	2,148,267
1848	1,521,370	1854	1,267,513
1849	1,655,300	1855	1,446,707

Astonishing as it may appear, the bulk of these importations have been consumed in England, and the quantity re-shipped to the Continent has been comparatively trifling in amount.

During the last ten years, the prices have fluctuated considerably. In 1844, one shilling and eightpence per pound was quoted as the price of the white fleece, and two shillings for the black one. In the year 1855, according to the price currents, the average rates were thus quoted :

	s.	d.		s.	d.
Alpaca, best white	2	6	to	2	8
Ditto, brown and black	2	6	„	2	8
Vicuna, best dark coloured	3	0	„	3	6
Llama	0	10½	„	1	3

But these quotations are undoubtedly higher for alpaca wool than the prices realised, which of late years have ranged from two shillings and twopence to two shillings and sixpence per pound.

LOAD. A burthen or freight. As the various quantities of material contained in a load cannot but be useful, the following table is borrowed from *Mr. P. L. Simmonds'* "*Trade Products*," *&c.*

Corn	5 qrs. or 40 bushels.	Coffee, in bags	12 cwt.
Straw	36 trusses or 11 cwt. 64 lbs.	Rice	10 cwt.
Old hay	18 cwt.	Timber—	
New hay	19 cwt. 32 lbs.	1 inch plank	600 square feet.
Bricks	500.	1½ inch „	400 „ „
Tiles	1000.	2 inch „	300 „ „
Lead ore (in Derbyshire)	9 dishes or nearly 3 cwt.	2½ inch „	240 „ „
		3 inch „	200 „ „
Bulrushes	63 bundles.	3½ inch „	170 „ „
Mortar	27 feet.	4 inch „	150 „ „

LOADSTONE, MAGNETIC IRON-STONE. (*Fer oxydulé*, Fr.; *Magneteisenstein*, Germ.) An iron ore consisting of the protoxide and peroxide of iron in a state of combination.

It was first discovered in Magnesia, and from that province has been derived the name MAGNET applied to this ore of iron. The term loadstone, however, is given to those specimens which are powerfully magnetic only. A considerable number of the igneous rocks containing iron are magnetic, and many magnetic oxides of iron are found in England, especially near Penryn in Cornwall, near Brent in Devonshire, at Rosedale in Yorkshire, and some other places. See IRON.

LOAM. (*Terre limoneuse*, Fr.; *Lehm*, Germ.) A native clay mixed with quarts sand and iron ochre, and occasionally with some carbonate of lime.

"More commonly we find sand and clay or clay and marl intermixed in the same mass. When the sand and clay are each in considerable quantities, the mixture is called 'loam.'"—*Lyell.*

LOCKS. Although locks are distinctly a manufacture, yet they were not embraced in former editions of this work, the chief cause of this being the desire on the part of Dr. Ure to limit the articles of the dictionary to such manufactures as were not comprehended within his meaning of the term handicraft.

The lock manufacture is essentially one of handicraft, and seeing that these volumes could not possibly enter into any detailed description of this and numerous other trades, as watchmaking and the like, it has been determined that a brief notice of the several kinds of locks alone shall find a place in its pages.

The lock manufacture of this country is confined almost exclusively to Wolverhampton and the neighbouring village of Willenhall. There are very few large manufactories, almost all kinds of locks being made by small masters, employing from half a dozen to a dozen men.

In nearly every kind of lock, a bolt shoots out from the box or lock, usually of an oblong shape, and catches in some kind of staple or box fixed to receive it. In some a staple enters the lock, and the bolt passes through the staple within the lock. The lock of a room door is of the first character. The lock of a writing desk, or ordinary box, is of the second kind. The key is merely a bent piece of iron which, on entering the lock, can move freely and push forward the bolt. To the bolts of superior locks springs are attached, and the force required to turn the key in a lock is the force necessary to overcome the resistance of the springs. The following two figures, 1143, 1144, represent the character of a lock with wards or wheels which are introduced to give safety. *Fig.* 1143 is an ordinary back spring lock, representing the bolt half shot ; a' a'' are notches on the under side of the bolt connected by a curved

portion; *b* is the back spring, which is of course compressed as the curved portion of the bolt passes through the aperture prepared for it in the rim of the lock; when

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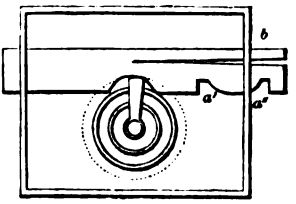

1144

the bolt is withdrawn, the notch *a'* rests in the rim; when the bolt is shot, the notch *a''* rests in the same manner. The action of the key and wards is shown in *fig.* 1144. The curved pieces of metal are the wards; and there are two clefts in the bit of the key to enable it to move without interruption.

The tumbler lock is shown in its most simple form in *fig.* 1145. Here the bolt has two slots *a a* in the upper part; and behind the bolt is a kind of latch *b* which carries a projecting piece of metal; *c*, this is the tumbler which moves freely on a pivot at the other end. When the bolt is fully shot the projecting piece of metal falls into one notch; and when withdrawn, it falls into the other. It will be evident here that the action of the key is to raise the tumbler, so that the bolt has free motion; this action will be intelligible by tracing the action of the key on the dotted lines. These tumbler locks are greatly varied in character; but in principle they are as above described. Numerous well known locks have been patented, the most remarkable being Chubb's lock, which has been fully described by the inventors in a paper read before the Institution of Civil Engineers; and also in an excellent treatise on locks to be found in Mr. Weale's series of useful manuals. This lock is essentially a tumbler lock, it being fitted up with no less than six tumblers; and the key has to raise by a series of steps these, before the bolt is free to move. It will be obvious, that unless the key is exactly fitted to move these, there is no chance of moving the bolt. In his paper already alluded to, Mr. Chubb says—

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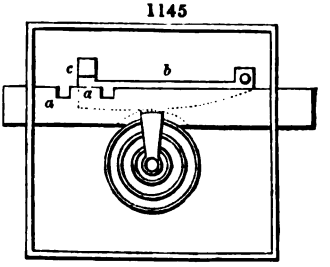

"The number of changes which may be effected on the keys of a three inch drawer lock is $1 \times 2 \times 3 \times 4 \times 5 \times 6 = 720$, the number of different combinations which may be made on the six steps of unequal lengths, without altering the length of either step. The height of the shortest step is however capable of being reduced 20 times; and each time of being reduced, the 720 combinations may be repeated; therefore $720 \times 20 = 14{,}400$ changes." By effecting changes of this character therefore, almost any number of combinations can be produced. The Bramah lock has been long celebrated, and most deservedly so. Notwithstanding the fact that this lock was picked by Mr. Hobbs after having the lock in his possession for sixteen days, it appears to us that it most fully justifies the boast made by Mr. Bramah in his "*Dissertation on the Construction of Locks.*" "Being confident," he says, "that I have contrived a security which no instrument but its proper key can reach, and which may be so applied as not only to defy the art and ingenuity of the most skilful workman, but to render the utmost force ineffectual, and thereby to secure what is most valued as well from dishonest servants as from the midnight ruffian, I think myself at liberty to declare (what nothing but the discovery of an infallible remedy would justify my disclosing) that all dependence on the inviolable security of locks, even of those which are constructed on the best principle of any in general use, is fallacious." He then proceeds to demonstrate the imperfections of ordinary locks and to describe his own.

"The body of a Bramah lock may be considered as formed of two concentric brass barrels, the outer one fixed, and the inner rotating within it. The inner barrel has a projecting stud, which, while the barrel is rotating, comes in contact with the bolt in such a way as to shoot or lock it; and thus the stud serves the same purpose as

the bit of an ordinary key, rendering the construction of a bit to the Bramah key unnecessary. If the barrel can be made to rotate to the right or left, the bolt can be locked or unlocked, and the problem is, therefore, how to insure the rotation of the barrel. The key, which has a pipe or hollow shaft, is inserted in the keyhole upon the pin, and is then turned round; but there must be a nice adjustment of the mechanism of the barrel before this turning round of the key and the barrel can be insured. The barrel has an external groove at right angles to the axis, penetrating to a certain depth; and it has also several internal longitudinal grooves from end to end. In these internal grooves thin pieces of steel are able to slide, in a direction parallel with the axis of the barrel. A thin plate of steel called the locking plate, is screwed in two portions to the outer barrel, concentric with the inner barrel; and at the same time occupying the external circular groove of the inner barrel; this plate has notches, fitted in number and size to receive the edges of the slides which work in the internal longitudinal grooves of the barrel. If this were all, the barrel could not revolve, because the slides are catching in the grooves of the locking plate; but each slide has also a groove, corresponding in depth to the extent of this entanglement; and if this groove be brought to the plane of the locking plate, the barrel can be turned, so far as respects the individual slide. All the slides must, however, be so adjusted, that their grooves shall come to the same plane; but, as the notch is cut at different points in the lengths of the several slides, the slides have to be pushed in to different distances in the barrel, in order that this juxtaposition of notches may be insured. This is effected by the key, which has notches or clefts at the end of the pipe equal in number to the slides, and made to fit the ends of the slides when the key is inserted; the key presses each slide, and pushes it so far as the depth of its cleft will permit; and all these depths are such that all the slides are pushed to the exact position where their notches all lie in the same plane; this is the plane of the locking plate, and the barrel can be then turned." (*Tomlinson on the Construction of Locks.*) In this work the details on construction are given with great clearness.

The American bank locks, especially that of Messrs. Day and Newall, have excited much attention. Their English patent describes it thus: —

"The object of the present improvements is the constructing of locks in such manner that the interior arrangements, or the combination of the internal movable parts, may be changed at pleasure according to the form given to, or change made in, the key, without the necessity of arranging the movable parts of the lock by hand, or removing the lock or any part thereof from the door. In locks constructed on this plan the key may be altered at pleasure; and the act of locking, or throwing out the bolt of the lock, produces the particular arrangements of the internal parts, which correspond to that of the key for the time being. While the same is locked, this form is retained until the lock is unlocked or the bolt withdrawn, upon which the internal movable parts return to their original position, with reference to each other; but these parts cannot be made to assume or be brought back to their original position, except by a key of the precise form and dimensions as the key by which they were made to assume such arrangement in the act of locking. The key is changeable at pleasure, and the lock receives a special form in the act of locking according to the key employed, and retains that form until in the act of unlocking by the same key it resumes its original or unlocked state. The lock is again changeable at pleasure, simply by altering the arrangement of the movable bits of the key; and the key may be changed to any one of the forms within the number of permutations of which the parts are susceptible." — April 15, 1851.

Mr. Hobbs who has been carrying out the manufacture of American locks in this country has introduced an inexpensive lock, which he calls a *protector lock*. The following description is borrowed from Mr. Charles Tomlinson's *Treatise on the Construction of Locks*: —

"When the American locks became known in England, Mr. Hobbs undertook the superintendence of their manufacture, and their introduction into the commercial world. Such a lock as that just described must necessarily be a complex piece of mechanism; it is intended for use in the doors of receptacles containing property of great value; and the aim has been to baffle all the methods at present known of picking locks, by a combination of mechanism necessarily elaborate. Such a lock must of necessity be costly; but in order to supply the demand for a small lock at moderate price, Mr. Hobbs has introduced what he calls a *protector lock*. This is a modification of the ordinary six-tumbler lock. It bears an affinity to the lock of Messrs. Day and Newall, inasmuch as it is an attempt to introduce the same principle of security against picking, while avoiding the complexity of the changeable lock. The distinction which Mr. Hobbs has made between secure and insecure locks will be understood from the following proposition, viz. 'that whenever the parts of a lock which come in contact with the key are so affected by any pressure applied to

the bolt, or to that portion of the lock by which the bolt is withdrawn, as to indicate the points of resistance to the withdrawal of the bolt, such a lock can be picked.' *Fig.* 1147 exhibits the internal mechanism of this new patent lock. It contains the usual contrivances of tumblers and springs, with a key cut into steps to suit the different heights to which the tumblers must be raised. The key is shown separately in *fig.* 1148. But there is a small additional piece of mechanism, in which the *tumbler stump* shown at *s* in *figs.* 1146 and 1147 is attached; which piece is intended to work under or behind the bolt of the lock. In *fig.* 1147, *b* is the bolt; *t t* is the front

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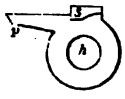

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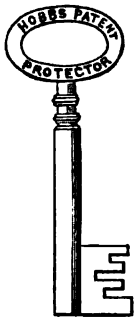

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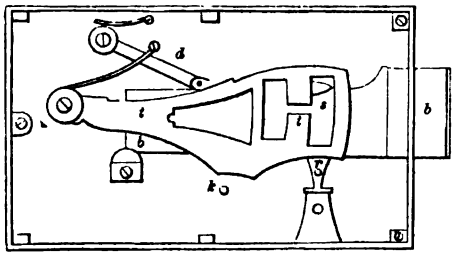

or foremost of the range of six tumblers, each of which has the usual slot and notches. In other tumbler-locks the stump or stud which moves along these slots is riveted to the bolt, in such manner that, if any pressure be applied in an attempt to withdraw the bolt, the stump becomes pressed against the edges of the tumblers, and bites or binds against them. How far their biting facilitates the picking of a lock will be shown further on; but it will suffice here to say, that the movable action given to the stump in the Hobbs lock transfers the pressure to another quarter. The stump *s* is riveted to a peculiarly-shaped piece of metal *h p* (*fig.* 1146), the hole in the centre of which fits upon a centre or pin in a recess formed at the back of the bolt; the piece moves easily on its centre, but is prevented from so doing spontaneously by a small binding spring. The mode in which this small movable piece takes part in the action of the lock is as follows: when the proper key is applied in the usual way, the tumblers are all raised to the proper heights for allowing the stump to pass horizontally through the gating; but should there be an attempt made, either by a false key or by any other instrument, to withdraw the bolt before the tumblers are properly raised, the stump becomes an obstacle. Meeting with an obstruction to its passage, the stump turns the piece to which it is attached on its centre, and moves the arm of the piece *p* so that it shall come into contact with a stud riveted into the case of the lock; and in this position there is a firm resistance against the withdrawal of the bolt. The tumblers are at the same moment released from the pressure of the stump. There is a dog or lever *d*, which catches into the top of the bolt, and thereby serves as an additional security against its being forced back. At *k* is the drill-pin on which the pipe of the key works; and *r* is a metal piece on which the tumblers rest when the key is not operating upon them.

Another lock, patented by Mr. Hobbs in 1852, has for its object the absolute closing of the key-hole during the process of locking. The key does not work or turn on its own centre, but occupies a small cell or chamber in a revolving cylinder, which is turned by a fixed handle. The bit of the movable key is entirely separable from the shaft or stem, into which it is screwed, and may be detached by turning round a small milled headed thumb-screw. The key is placed in the key-hole in the usual way, but it cannot turn; its circular movement round the stem as an axis is prevented by the internal mechanism of the lock; it is left in the key-hole, and the stem is detached from it by unscrewing. By turning the handle, the key-bit, which is left in the chamber of the cylinder, is brought into contact with the works of the lock, so as to shoot and withdraw the bolt. This revolution may take place whether the bit of the movable key occupy its little cell in the plate or not; only with this difference — that if the bit be *not* in the lock, the plate revolves without acting upon any of the tumblers; but if the bit be in its place, it raises the tumblers

in the proper way for shooting or withdrawing the bolt. It will be understood that there is only one key-hole, namely, that through which the divisible key is inserted; the other handle or fixed key working through a hole in the cover of the lock only just large enough to receive it, and not being removable from the lock. As soon as the plate turns round so far as to enable the key-bit to act upon the tumblers, the key-hole becomes entirely closed by the plate itself, so that the actual locking is effected at the very time when all access to the interior through the key-hole is cut off. When the bolt has been shot, the plate comes round to its original position, it uncovers the key-hole, and exhibits the key-bit occupying the little cell into which it had been dropped; the stem is then to be screwed into the bit, and the latter withdrawn. It is one consequence of this arrangement, that the key has to be screwed and unscrewed when used; but through this arrangement the keyhole becomes a sealed book to one who has not the right key. Nothing can be moved, provided the bit and stem of the key be both left in; but by leaving in the lock the former without the latter, the plate can rotate, the tumblers can be lifted, and the bolt can be shot.

LOCOMOTIVE ENGINES. The character of this work excludes any special notice of a subject so entirely belonging to a work on Mechanical Engineering, as that of locomotive engines. Nevertheless, since so much has lately been said and written on the question of employing coal on our railways instead of coke, we are induced to introduce the following arrangement, which secures combustion without smoke. It is known as Dumery's plan. The annexed drawing, *fig.* 1149, is a section of a locomotive engine, used on the Chalons Railway. The coal is thrown into the side pipes A B, which open below the platform on which the engine-man stands. These pipes conduct the coal by their own gravity to the lower level of the bars, where they are thrust in the direction of the arrows C D, by a kind of comb, or rotating pin, which in its rotation around the axle E, forces the coal to ascend the incline forward by the bars.

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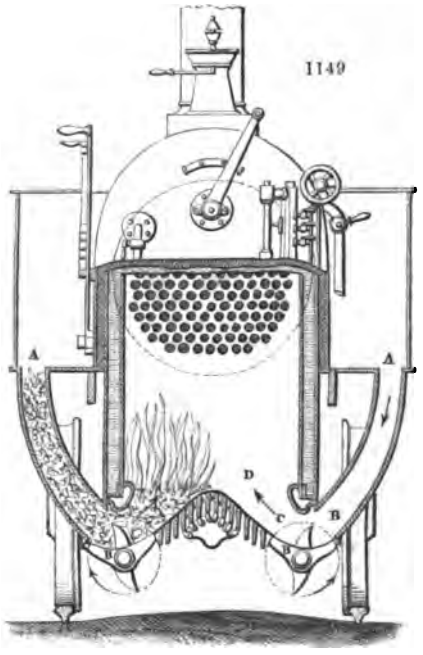

This then takes place, the coal in its rude state (*i. e.* as it comes from the pit) coming from below, finds itself immediately in contact with the fire, which induces an escape of the gases, and with the pure air which permits their combustion to take place in the only condition in which it is possible, *i. e.* in small jets, which facilitate the complete oxygenation of all the parts.

The gases once produced and burnt, the rest of the operation scarcely needs explanation. The coal is converted into coke, and finishes its passage while burning under this form: and as the remainder of the solids, cinders and slag (or clinkers), are not abandoned by the fire until after all that it contains of a combustible nature has disappeared, all the detritus (refuse) and dust, cinders, ashes, &c. are deposited on the surface (*sommet*) of the bars in the centre of the fire, where they would offer an obstruction similar to that found in ordinary fire-places, if the inventor had not taken care to make the bars oscillate from the centre by a small movement. Thus, when a drop of slag approaches the bars, it is displaced and thrown out (by the opening of the bars) in small particles. This accessory arrangement apparently possesses great advantages for a locomotive in saving the trouble of scraping and cleaning the bars.

So if, as in an ordinary fire, coke or anthracite, &c., be burnt, the combustion would be very complete. Air fresh from the ash-pan, in passing over the combustible, would be converted into carbonic acid, *i. e.* into a gas which is unfit for further combustion. But if in the place of coke or anthracite, &c. we use smoke-producing coal, *i. e.* com-

posed of two elements, one solid, the other gaseous, this result follows. The combustible gases disengaging themselves (in this case above the combustible) in a state of ignition, the air which will become vitiated in traversing the first bed of the solid combustible, will be found unable to effect the combustion of the gases which escape above the fire, and smoke will make its appearance *i. e.* the combustion will be incomplete and imperfect. This is what takes place with combustion of coal in ordinary fire-places.

There are also other causes which contribute to the imperfection of this result. These gases in disengaging themselves do not always acquire a temperature sufficiently high to produce flame, and the volume of combustible gas is almost always too considerable to allow of its being sufficiently penetrated with oxygen. These are some of the radical vices which M. Duméry has removed in thus placing the gases at once in the condition best suited for their combustion. This process is admirable, since, without any preparation, it allows of coal being burnt with as much facility as coke, and saves the great expense of converting coal into coke.

LOCUST TREE. A North American tree, the *Robinia pseudacacia*. "It grows most abundantly in the southern States; but it is pretty generally diffused through the whole country. It sometimes exceeds four feet in diameter and seventy feet in height. The locust is one of the very few trees planted by the Americans."—*Stevenson's Civil Engineering of North America*. This wood is much used for ships' tree-nails, and is employed for stakes and pales.

LODE (*a mining term*). A mineral lode, or a mineral vein, is the name given to a fissure in the crust of the earth which has been filled in with metalliferous matter. The miner gives the same name *lode* to a fissure filled with quartz, carbonate of lime, &c., but then he says the lode is not "mineralised," confining the word mineral to metalliferous matter.

The term *vein* has frequently led to the idea that it expresses the condition of something analogous to the blood vessels of the animal body, to which a lode has not in the remotest degree, any resemblance. During some primary convulsions, the crust of the earth has been cracked, these fissures having, of course, some special relation to the direction of the force which produced them. These cracks have during ages of submergence been filled in, according to some law of polarity with mineral matter, the character of the lode having generally some special relation to its direction. See MINING, &c.

LOGWOOD (*Bois de Campèche, Bois bleu*, Fr.; *Blauholz*, Germ.) is the wood of the *Hæmatoxylon Campechianum*, a native tree of Central America, grown in Jamaica since 1715. It was first introduced into England in the reign of Elizabeth, but as it afforded to the unskilful dyers of her time a fugitive colour, it was not only prohibited from being used, under severe penalties, but was ordered to be burned wherever found, by a law passed in the 23rd year of her reign. The same prejudice existed, and the same law was enacted against indigo. At length, after a century of absurd prohibition, these two most valuable tinctorial matters, by which all our hats, and the greater part of our woollen cloths, are dyed, were allowed to be used. The logwood trees grow from 40 to 50 feet high, the stems are cut into logs of about 3 feet long, the bark and white sap (alburnum) of which are chipped off, the heart or red part only being sent to England. Chevreul gave the constituents of logwood as *volatile oil, hæmatin, resinous matter, tannin, glutinous matter, acetic acid*, sundry salts of lime, with *alumina, silica, manganese, and iron*. The decoction of logwood is of a deep dull red, which is rendered paler and of a brighter colour by acids. Alkalies give it a purplish or violet colour. Acetate of lead causes a blue, alum a violet precipitate; the salts of iron make it a dark violet blue, gelatine forming a reddish precipitate with it.

Old wood, with black bark and with little of the white alburnum, is preferred. Logwood is denser than water, specific gravity, 1·057, very hard, of a fine compact grain, and almost indestructible by the atmospheric elements; it has a sweet and astringent taste, and a peculiar but inoffensive smell, and will take a fine polish.

When chipped logwood is for some time exposed to the air, it loses a portion of its dyeing power. Its decoction absorbs the oxygen of the atmosphere, and then acquires the property of precipitating with gelatine, which it had not before. The dry extract of logwood, made from an old decoction, affords only a fugitive colour.

For its applications in dyeing, see BLACK DYE; CALICO PRINTING; DYEING; HAT DYEING, &c.

The *imports* of logwood were in

	Tons.	Value
1855	30,215	£192,795
1856	38,880	264,330
1857	39,568	236,080

LOOKING GLASS. See MIRRORS.

LOOM (*Metier a tisser*, Fr.; *Weberstuhl*, Germ.) is the ancient and well-known machine for weaving cloth by the decussation of a series of parallel threads, which run lengthwise, called the warp or chain, with other threads thrown transversely with the shuttle, called the woof or weft. See JACQUARD LOOM and WEAVING.

LUBRICANTS. Oleaginous or fatty bodies employed for the purpose of reducing the friction between two parts of a machine or carriage.

LUBRICATION. The lubrication of the wheel and axle of railway carriages is effected by a kind of soap, a combination of cocoa-nut oil or palm-oil, or ordinary fats, with soda being the "grease" with which the boxes are filled. The heat produced by the friction melts the grease, and it flows out upon the parts in motion through an opening in the bottom of the box. Heavy machinery, such as pumping engines, require tenacious bodies as their lubricants, while the finer parts must be carefully oiled with oils as free as possible from any of the fatty acids. Spinning machinery for example, must be lubricated with the finest oils, or, as is found to be still better, with those peculiar hydro-carbon compounds, as paraffine, glycerine, and the like. The following is a simple and efficacious plan of lubricating the joints and bearings of machinery by capillary attraction, the invention of Edward Woolsey, Esq.:—

Fig. 1150 represents a tin cup, which has a small tin tube A, which passes through the bottom, as shown by the dotted lines. It may have a tin cover to keep out the dust.

Fig. 1151 is a plan of the same.

Fig. 1152 is a section of the same. Oil is poured into the cup, the one end of a worsted or cotton thread is dipped into the oil, and the other end passed through the tube.

The capillary attraction causes the oil to ascend and pass over the orifice of the tube, whence it gradually descends, and drops slower or quicker according to the length of the thread or its thickness, until every particle of oil is drawn over by this capillary siphon. The tube is intended to be put into the bearings of shafts, &c., and is made of any size that may be wished. If oil, or other liquids, is desired to be dropped upon a grindstone or other surface, this cup can have a handle to it, or be hung from the ceiling.

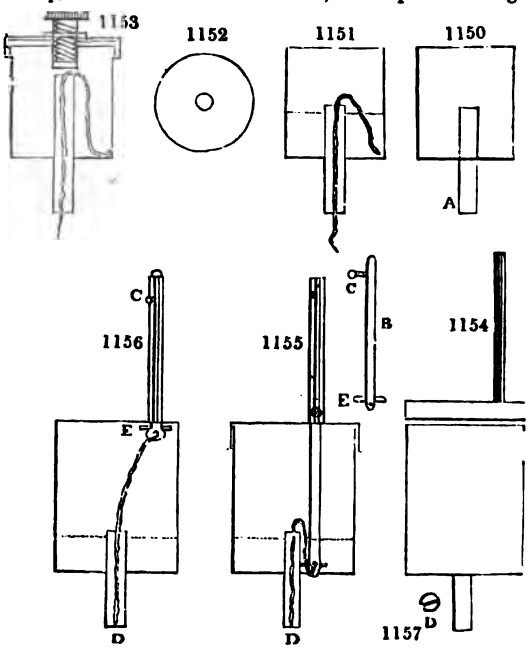

Fig. 1153. It is frequently required to stop the capillary action when the machinery is not going; and this has been effected by means of a tightening screw, which passes through a screw boss in the cover of the cup, and presses against the internal orifice of the tube, preventing the oil from passing.

Fig. 1154. As when these screw cups are used upon beams of engines and moving bearings, the screw is apt to be tightened by the motion; and also, as the action of the screw is uncertain, from the workman neglecting to screw it down sufficiently, it answers best to take out the capillary thread when the lubrication is not required; and to effect this easily, a tin top is fixed to the cup, with a round pipe soldered to it; this pipe has a slit in it, like a pencil case, and allows a bolt B to slide easily. In *fig.* 1155 the bolt is down; in *fig.* 1156 the bolt, which is a piece of brass wire, is drawn up, and thus the flowing of the oil is checked. In *fig.* 1156 it will be observed, that the bolt is kept in its place by its head C, resting in a lateral slit in the pipe, and it cannot be drawn out on account of the pin E. One end of the thread is fastened to the eye hole at the bottom of the bolt, and the other end is tied to a small wire which crosses the lower orifice of the tube at D, and which is shown in plan *fig.* 1157.

The saving by this plan, instead of pouring oil into the bearings, is 2 gallons out of 3, while the bearings are better oiled.

The saving in labour is considerable where there are many joints to keep oiled three or four times a day; and the workman does not, with this apparatus, run the risk of being caught by the machinery. To tie on the cotton or worsted thread, pass a long thread through the eye-hole E of the bolt, and then draw the two ends through the tube by a fine wire with a hook to it, one end on one side of the cross wire D, and the other end on the other side. Then put the cover on, and the bolt in the position shown in *fig.* 1156; when by drawing the two ends of the thread, and tying them across the wire D, you have the exact length required. When you wish to see the quantity of oil remaining in the lubricator, the bolt must be dropped as in *fig.* 1155, and you can then lift the cover a little way off, without breaking the thread, and replenish with oil. The figures in the woodcuts are one third of the full size.

LUCIFER MATCHES. The importance of this manufacture has been shown by Mr. Tomlinson in a communication made by that gentleman to the journal of the Society of Arts.

"It has been estimated," he says, "that the English and French manufacturers of phosphorus are now producing at the rate of 300,000 lbs. of common phosphorus per annum, nearly the whole of which is consumed in making lucifer matches. In compounding the emulsion for tipping the matches, the German manufacturers make three pounds of phosphorus suffice for five or six millions of matches. If we suppose only one half of the French and English annual product of phosphorus to be employed in making matches, this will give us 250,000,000,000 of matches as the annual product consequent on the consumption of one half of the French and English phosphorus. We need not suppose this to be an exaggerated statement, when we consider the daily product of some of our match manufactories. I lately had occasion to describe the processes of a London factory, which produces 2,500,000 matches daily. For this purpose, 14 3-inch planks are cut up; each plank produces 30 blocks; each block, of the dimensions of 11 inches long, 4½ inches wide, and 3 inches thick, produces 100 slices, each slice 31 splints, each splint 2 matches: thus we have—$14 \times 30 \times 100 \times 31 \times 2 = 2{,}604{,}000$ matches as the day's work of a single factory in London. At Messrs. Dixon's factory near Manchester, from 6,000,000 to 9,000,000 of matches are produced daily."—*Tomlinson.*

For the rapid manufacture of the wooden splints for lucifer matches, a patent was obtained by Mr. Reuben Partridge, in March, 1842. He employs a perforated metallic plate, having a steel face, strengthened by a bell metal back; see *figs.* 1158, 1159. The size of the perforations must depend on that of the desired splints, but they

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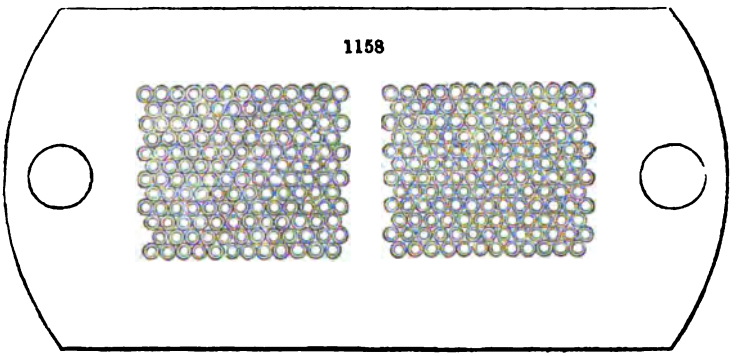

1159

must be as close together as possible, that there may be a very small blank space between them, otherwise the plate would afford too great resistance to the passage of the wood. By this construction, the whole area of the block of wood may be compressed laterally into the countersunk openings, and forced through the holes, which are slightly countersunk to favour the entrance and separation of the wooden fibres.

Fig. 1158 represents the face of one of these plates; and *fig.* 1159 is a rectangular section through the plate. A convenient size of plate is three inches broad, six inches long, and one thick. The mode of pressing is by fixing the back of the plate against a firm resisting block or bearing, having an aperture equal to the area of the perforations in the plate, and then placing the end of the piece or pieces of wood in the direction of the grain against the face of the plate within the area of the perforated portion. A plunger or lever or other suitable mechanical agent being then applied to the back or reverse end of the piece of wood, it may be forced through the perforations in the plate, being first split as it advances by the cutting edges of the holes, and afterwards compressed and driven through the perforations in the plate, coming out on the opposite side or back of the plate in the form of a multitude of distinct splints, agreeably to the shapes and dimensions of the perforations.—*Newton's Journal*, C. S. vol. xxii. 268.

Manufacture of Lucifers.—The first stage in the manufacture of lucifers is the cutting the wood, which is done, according to the extent of the manufactory, either by hand or by machinery. This, as well as the subsequent process of counting and placing the matches in frames, is in itself necessarily free from any inconvenience or evil consequences; nor does it appear that the third stage, which consists of melting the sulphur and dipping the heads of the matches in it, produces any inconvenience. The fourth, fifth, sixth, and seventh stages comprise the grinding, mullering, and mixing of the explosive compound; the process of dipping the matches in it, the counting and boxing. The dipping, counting, and packing, appear to be, according to Mr. Geist, the only departments in which the workpeople are in any way affected with peculiar complaints; we would even limit the appearance of the jaw disease to those engaged in dipping; at least all that we have examined on the subject were unanimous as to the fact that dippers only were attacked. There is a certain degree of secrecy observed relative to the proportions of the composition; and the mixture of the materials is generally performed by the proprietor of the manufactory, or by a confidential workman. Chlorate of potash is considered an essential ingredient in England; but in the manufactories at Nürnberg it has not been employed for a number of years, as its explosive properties much endangered the safety of the buildings and the limbs of the workmen.

The composition used in Nürnberg consists of one-third of phosphorus, of gum arabic (which is eschewed by English manufacturers on account of its hygrometric property), of water, and of colouring matter, for which either minium or Prussian blue is employed. If ignition be required without a flame, the quantity of phosphorus is diminished, or nitrate of lead is added. The mixing is conducted in a water-bath; and during this process, and as long as the phosphorus is being ground or "mullered," copious fumes are evolved. The dipping is performed in the following manner:—The melted composition is spread upon a board covered with cloth or leather, and the workman dips the two ends of the matches alternately that are fixed in the frame; and as this is done with great rapidity, the disengagement of fumes is very considerable, and the more liable to be injurious, as they are evolved in a very concentrated form close to the face of the workman. This department is generally left to a single workman; and the average number that he can dip in an hour, supposing each frame to hold 3,000 matches, would be 1,000,000.

As the matches have been dipped, they require to be dried. This is generally done in the room in which the former process is carried on; and as a temperature of from 80° to 90° Fahr. is necessary, the greatest quantity of fumes is evolved at this stage. When the matches are dried, the frames are removed from the drying room, and the lucifers are now ready to be counted out into boxes. As this is done with great rapidity, they frequently take fire, and, although instantly extinguished in the sawdust or the water which is at hand, the occurrence gives rise to an additional and frequent evolution of fumes.

According to Dr. R. Boettger, in *Annalen der Chemie und Pharmacie*, vol. xlvii. p. 334, the best composition for lucifer matches is

Phosphorus - - -	4 parts	Red ochre, or red lead	5 parts
Nitre - - -	10 „	Smalt - - -	2 „
Fine glue - - -	6 „		

Convert the glue with a little water by a gentle heat into a smooth jelly, put it into a slightly warm porcelain mortar to liquefy; rub the phosphorus down through this gelatine at a temperature of about 140° or 150° Fahr.; add the nitre, then the red powder, and lastly the smalt, till the whole forms a uniform paste. To make writing-paper matches, which burn with a bright flame and diffuse an agreeable odour, moisten each side of the paper with tincture of benzoin, dry it, cut it into slips, and smear one of their ends with a little of the above paste by means of a hair pencil. On rubbing the said end after it is dry against a rough surface the paper will take fire, without the intervention of sulphur.

To form lucifer wood matches, that act without sulphur, melt in a flat-bottomed

tin pan as much white wax as will stand one-tenth of an inch deep; take a bundle of wooden matches free from resin, rub their ends against a red hot iron plate till the wood be slightly charred; dip them now in the melted wax for a moment, shake them well on taking them out, and finally dip them separately in the above viscid paste. When dry, they will kindle readily by friction.

A "*Safety Lucifer Match*," as it is called, has been manufactured in Sweden. A patent was obtained in that country by Messrs. Bryant and May, for this match. Its peculiarity consists in the division of the combustible ingredients of the lucifer between the match and the friction paper. In the ordinary lucifer, the phosphorus, sulphur, and chlorate of potash or nitre, are all together on the match, which ignites when rubbed against any rough substance. In the Swedish matches these materials are so divided that the phosphorus is placed on the sand-paper, whilst the sulphur and a minimum amount of chlorate or nitrate of potash is placed on the match. In virtue of this arrangement it is only when the phosphorised sand-paper and the sulphurised match come in contact with each other that the ignition occurs. Neither match nor sand-paper, singly, takes fire by moderate friction against a rough surface.

The composition of lucifer matches varies greatly, as it regards the proportions of the materials employed. In principle they are, however, as we have described them above; everything depending on the ignition of the phosphorus, and the perfection of a lucifer match is in tipping the match with a composition which will ignite quietly upon attrition against any rough surface, but which is not liable to ignition by such pressure as it may be subjected to under the ordinary condition of keeping in closed boxes.

The preparation of lucifer matches has been attended with much human suffering. Every person engaged in a factory of this kind is more or less exposed to the fumes of phosphorus, and this exposure produces a disease which has been thus described by Mr. Harrison, in the *Quarterly Journal of Medical Science*.—"This disease," he says, "is of so insidious a nature that it is at first supposed to be common toothache, and a most serious disease of the jaw is produced before the patient is fully aware of his condition. The disease gradually creeps on, until the sufferer becomes a miserable and loathsome object, spending the best period of his life in the wards of a public hospital. Many patients have died of the disease; many, unable to open their jaws, have lingered with carious and necrosed bones; others have suffered dreadful mutilations from surgical operations, considering themselves happy to escape with the loss of the greater portion of the lower jaw."

By the introduction of an amorphous phosphorus discovered by M. Schrötter, which is in nearly all respects unlike the ordinary phosphorus, but which answers exceedingly well for the manufacture of lucifer matches, this disease is prevented, the manufactory is rendered more healthy, and the boxes of matches themselves less dangerous. See PHOSPHORUS. In 1857 our imports and exports were—

Imports—Lucifers—Wood, No.	-	-	155,153	- £29,091
„ Vesta of Wax	-	-	17,395,210	- 1450
Exports—Lucifers—Wood (Cubic Feet)	-		10,628	- £1993
„ Vesta of Wax, No.	-		5,604,480	- 47

LUMACHELLE, or Fire Marble. This is a dark brown shelly marble, having brilliant fire or *chatoyant* reflections from within.—See MARBLE.

LUNAR CAUSTIC. A name for nitrate of silver, when fused and run into cylindrical moulds.

LUPININE, is a substance of a gummy appearance, so named by M. Cussola, because it was obtained from Lupines.—C. G. W.

LUPULINE, from *Humulus Lupulus*; is the peculiar bitter aromatic principle of the hop. See BEER.

LUSTRING, sometimes spelled and pronounced Lutestring; a peculiar shining silk.

LUTE (from *lutum*, clay; *Lut*, Fr.; *Kitte*, *Beschläge*, Germ.) is a pasty or loamy matter employed to close the joints of chemical apparatus, or to coat their surfaces, and protect them from the direct action of flame. Lutes differ according to the nature of the vapours which they are destined to confine, and the degree of heat which they are to be exposed to.

1. *Lute of linseed meal*, made into a soft plastic dough with water, and immediately applied pretty thick to junctions of glass, or stone-ware, makes them perfectly tight, hardens speedily, resists acid and ammoniacal vapours, as also a moderate degree of heat. It becomes stronger when the meal is kneaded with milk, lime-water, or solution of glue, and is the best lute for fluo-silicic acid.

2. Lute of thick gum-water, kneaded with clay, and iron filings, serves well for permanent junctions, as it becomes extremely solid.

3. By softening in water a piece of thick brown-paper, kneading it, first with rye-flour paste, and then with some potter's clay, till it acquire the proper consistence, a lute is formed which does not readily crack or scale off.

4. Lute, consisting of a strong solution of glue kneaded into a dough with new slaked lime, is a powerful cement, and with the addition of white of egg forms the *lut d'ane;* — a composition adapted to mend broken vessels of porcelain and stone-ware.

5. Skim-milk cheese, boiled for some time in water, and then triturated into paste with fresh-slaked lime, forms also a good lute.

6. Calcined gypsum, diffused through milk, solution of glue, or starch, is a valuable lute in many cases.

7. A lute made with linseed, melted caoutchouc, and pipe-clay, incorporated into a smooth dough, may be kept long soft when covered in a cellar, and serves admirably to confine acid vapours. As it does not harden, it may therefore be applied and taken off as often as we please.

8. Caoutchouc itself, after being melted in a spoon, may be advantageously used for securing joints against chlorine and acid vapours, in emergencies when nothing else would be effectual, or we may use 1 part of caoutchouc dissolved in two parts of hot linseed-oil, and worked up with pipe-clay (3 parts) into a plastic mass. It bears the heat at which sulphuric acid boils.

9. The best lute for joining crucibles inverted into each other, is a dough made with a mixture of fresh fire-clay, and ground fire-bricks, worked with water. That cement, if made with solution of borax, answers still better, upon some occasions, as it becomes a compact vitreous mass in the fire.

LUTEOLINE, is the colouring principle of the weld (*Reseda luteola*), a slender plant growing to the height of about three feet, and cultivated for the use of dyers. When ripe it is cut and dried.

Chevreul was the first to separate the *luteoline;* it is extracted from the weld by boiling water, and when this solution is concentrated and allowed to cool, the luteoline separates; it is then collected, dried, and submitted to sublimation, when it is condensed in yellow needles.

It is valued for its durability, and is used as a yellow dye, on cottons principally, and also on silks, but is little used at present. It was formerly used by paper-hanging manufacturers, to form a yellow pigment, but has been entirely superseded for that purpose, by *quercitron bark* and *Persian berries*. It unites with acids and alkalies, the former making the colour paler, and the latter heightening the colour. The compound which it forms with potash is of a golden colour, becoming greenish when exposed to the air, by absorption of oxygen, and at length becomes red.

It forms yellow compounds with alum, protochloride of tin, and acetate of lead; with the salts of iron it produces a blackish grey precipitate, and with sulphate of copper a greenish brown precipitate.

It is readily soluble in alcohol and ether, but sparingly so in water.—H. K. B.

LUTIDINE, $C^{14}H^9N$. A volatile nitryle base, discovered by Anderson in bone oil. It has also been found in shale naphtha, coal naphtha, and in crude chinoline. — C. G. W.

LYCOPODIUM CLAVATUM. The seeds of the lycopodium ripen in September. They are employed, on account of their great combustibility, in theatres, to imitate the sudden flash of lightning, by throwing a quantity of them from a powder puff, or bellows, across the flame of a candle.

LYDIAN STONE, *Touchstone*, or *Basanite*. A flinty variety of jasper, used on account of its hardness, fine texture, and velvet black colour, for trying the purity of the precious metals. The amount of alloy is indicated by the colour left on the stone after the metal has been rubbed across it.

LYNX.—An animal producing a favourite fur of a greyish white, with dark spots.

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